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PRODUCTION, DISTRIBUTION, USE AND ENVIRONMENTAL IMPACT POTENTIAL OF SELECTED PESTICIDES

MIDWEST RESEARCH INSTITUTE

PREPARED FOR
COUNCIL ON ENVIRONMENTAL QUALITY
RVR CONSULTANTS

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The production, distribution, use patterns, and potential for environmental impacts of pesticides are described, with emphasis on 25 important pesticides that were selected by applying a priority rating system to 125 major pesticides. Information on environmental impact potential, wasteful use practices, and alternative methods of pest control are discussed in general and in particular for each of the intensive-study pesticides.

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Fungicides and wood preservatives: captan, creosote, nameb, pentachlorophenol
Fumigants: methyl bromide, dichlorobenzene
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PRODUCTION, DISTRIBUTION, USE AND ENVIRONMENTAL IMPACT POTENTIAL OF SELECTED PESTICIDES

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722 Jackson Place
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PREFACE

This report presents the results of a study conducted by Midwest Research Institute and RvR Consultants under Contract No. EQC-311 from the Council on Environmental Quality with the support of the Environmental Protection Agency. The project staff for Midwest Research Institute (MRI Project No. 3749-C) consisted of Dr. Edward W. Lawless, Project Leader, Dr. Alfred F. Meiners, Ms. Kathryn Lawrence and Mr. Gary L. Kelso. The project staff for RvR Consultants (RvR Project No. 29, under subcontract to MRI) consisted of Dr. Rosmarie von Rümker, Project Leader, and Mrs. Freda Horay.

Dr. Alvin Hylton, Mr. Charles Mumma and Mr. Howard Gadberry of the MRI staff assisted the project team. Dr. Dale Young, Mr. James L. Sullens, Mr. Roland Rhodes, Mr. Charles A. Patterson and Mr. William Bell were utilized as consultants on the program. The assistance of the many authorities on pesticide manufacture, use, and impact, who contributed their time and helpful information to this study, is gratefully acknowledged, and our special thanks goes to Mr. William Wymer and the Federal Working Group on Pest Management for compiling the data on pesticide use by the federal government.

Project Officers for the CEQ have been Dr. J. C. Davies, III, and Dr. Warren Muir, and Mr. Charles Reese, Dr. Jay Turim and Mr. Ted Breton were advisors for the EPA.

Approved for:

MIDWEST RESEARCH INSTITUTE

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1 August 1974

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ABSTRACT

The production, distribution, use patterns and potential for environmental impacts of pesticides are described, with emphasis on 25 important pesticides that were selected by applying a priority rating system to 125 major pesticides. The domestic consumption of these 25 intensive-study products was estimated by analyses of data from several complementary sources, including information on the supply of each material and on each of its important uses. Government statistics on pesticide production, import and export were analyzed and combined with information from other published sources, personal contacts and a study of use practices (as discussed below) to estimate the total domestic use of each of the 25. The proportions of these uses were estimated for each of six geographical regions and four major user categories, i.e., the agricultural, industrial/commercial/institutional, governmental agencies, and home and garden sectors.

Data from federal, state and other sources on the domestic agricultural use of pesticides were analyzed in depth, and efforts were made to resolve significant information gaps and discrepancies. The 25 intensive-study pesticides were analyzed according to use by crop and target pest before making final estimates of total use by geographical region. A broad study was made of the use of pesticides in the industrial, commercial and institutional sectors. The major pesticide users were characterized by type of organization, their pest problems, and the quantities of pesticides utilized. The total amounts of the 25 intensive-study pesticides used in these sectors and their use by geographical regions were then estimated. A study of the use of pesticides by government agencies employed data from two sources. The Federal Working Group on Pest Management supplied data on the proposed use of individual pesticides by specific facilities; the total quantity of each pesticide used by all federal agencies and the quantities of major pesticides used by each agency were then calculated or estimated. Original questionnaires on the use of pesticides by governmental agencies were sent to purchasing agents in the 48 contiguous states and 50 selected cities. Based on the data received, the total use of the 25 intensive-study products by state and city agencies was estimated by extrapolations based on population. Finally, estimates were made for the total use of 25 pesticides by all agencies of government.

A study of pesticide use in the home and garden sector was not a goal of original research on the project. Where necessary to complete the 25 case studies, amounts of pesticides used in this sector were derived by difference between production and other uses and by a general knowledge of the field.

The 25 intensive-study pesticides were as follows: Insecticides - aldrin, carbaryl, carbofuran, chlordane, diazinon disulfoton, malathion, methyl parathion, parathion, toxaphene; Herbicides - alachlor, atrazine,

bromacil, 2,4-D, diuron, MSMA, sodium chlorate trifluralin; Fungicides and Wood Preservatives - captan, creosote, nameb, and pentachlorophenol; Fumigants - methyl bromide, and dichlorobenzene; and Special Category - organotin compounds.

The U.S. production of these 25 pesticides was 2.07 billion pounds of active ingredient. However, one pesticide, creosote (0.99 billion pounds), accounted for almost half of this total. Domestic consumption was 1.54 billion pounds total (0.56 billion pounds of pesticides excluding creosote).

The distribution by user category for these 25 pesticides was: industrial/commercial/institutional, 71% (excluding creosote, 23%); governmental, 1% (excluding creosote, 2%); home and garden, 5% (excluding creosote, 12%); and agricultural, 23% (excluding creosote, 63%).

Information on environmental impact potential, wasteful use practices, and alternative methods of pest control are discussed in general and in particular for each of the intensive-study pesticides.

I. INTRODUCTION

Pesticides constitute an important aspect of modern life. They make important contributions to the production of food and fiber, the preservation of structures and materials, and the control of species that carry disease, are poisonous, or are obnoxious to humans. But they have caused serious concern that their widespread use can cause adverse effects on the environment and on human health. The evaluation of the overall environmental impact of pesticides is extremely difficult, however, because of the large number of different pesticidal chemicals that are used, the wide variations in their properties and use patterns, and the inadequacy of the available data on quantities of pesticides produced and amounts used in particular applications or geographical regions.

The Council on Environmental Quality and the Environmental Protection Agency have been very interested in developing the general and specific information needed to make this evaluation. EPA, through its Pesticide Study Series, has supported investigations of the manufacture and production of pesticides,[1] and their use in various specific applications and geographical regions,[2-8] and to summarize current research programs,[9] and the results of all research to date[10] on the effects of pesticides in the aquatic environment. CEQ has supported a search for general environmental indicators for pesticides,[11] and has pointed out[12] that a "materials balance" approach to pesticides would be most helpful in understanding their impacts. CEQ has noted, however, that more systematic and comprehensive data are needed on the production, supply, movement and application of pesticides as well as on their levels throughout the environment. The Congressional Reference Service has also informed the Congress directly of this need.[13] This study will help in part to fill that need.

A. Objectives of the Study

The long-range goal of this study has been to help develop an overview of the environmental impacts of the approximately 250 commercially important pesticides that are produced or used in the United States. Objectives have been: (a) to develop fundamental data on the production of pesticides; (b) to develop data on the United States consumption of pesticides in three of the four major user classifications--agricultural; industrial, commercial and institutional; and governmental;* (c) to identify the factors that may contribute to adverse environmental impacts;

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* A detailed study of a fourth major area, the home and garden use of pesticides, was specifically excluded from the present program by funding limitations.

(d) to develop detailed information on the production, distribution, use and environmental impact potentials of a number of selected pesticides that would be representative of pesticides in general; and (e) to analyze and summarize all of this information in terms of the long-range goal.

B. The Study Approach

The approach centered on the development of detailed information on selected "intensive-study" pesticides, but information was developed concurrently on the production, use, and impacts of pesticides in general. The investigation has seven tasks as follows:

1. Establish a priority system to select pesticides of major interest to CEQ/EPA and select ~ 25 pesticides for systematic study. The 25 selected intensive-study pesticides are listed on p. 3 and details of the selection procedure are given in Appendix A.

2. Compile information on the production of all pesticides and on the manufacture, formulation and distribution of the intensive-study pesticides (including pollution control technology).

3. Compile an inventory and analysis of the agricultural uses of pesticides, with emphasis on the intensive-study pesticides.

4. Compile an inventory and analysis of the industrial, commercial and institutional uses of pesticides, with emphasis on the intensive-study pesticides.

5. Compile an inventory and analysis of use of pesticides by federal, state and local governmental agencies, with emphasis on the intensive-study pesticides.

6. Develop materials-flow diagrams for each of the intensive-study pesticides which illustrate geographically the following movements of materials: (a) raw materials to the pesticide manufacturing site, (b) by-products and wastes into the environment, and (c) the active ingredient to the various parts of the country.

7. Summarize actual and potential impacts on man and on the environment for each of the intensive-study pesticides, and analyze available and practical chemical and nonchemical alternatives. Extend these results to pesticides in general.

A "case study" was then prepared for each of the 25 intensive-study pesticides as presented in Chapter X, and other results and conclusions of the investigation were summarized, as presented in Chapters III to IX of this report.

LIST OF 25 INTENSIVE-STUDY PESTICIDES

Insecticides

Aldrin
Carbaryl
Carbofuran
Chlordane[a]
Diazinon
Disulfoton
Malathion
Methyl Parathion
Parathion
Toxaphene

Fungicides and Wood Preservatives

Captan
Creosote
Maneb
Pentachlorophenol[c]

Special Category

Organotin Compounds

Herbicides

Alachlor
Atrazine
Bromacil
2,4-D
Diuron
MSMA
Sodium Chlorate[b]
Trifluralin

Fumigants

p-Dichlorobenzene[d]
Methyl Bromide[e]

---

[a] Includes use as termite treatment of wood structures.

[b] Includes mixtures with borates.

[c] Includes herbicidal use.

[d] Includes lavatory-space deodorant uses.

[e] Includes soil sterilization for weeds and insects and structural termite treatment.

II. CONCLUSIONS

Pesticides make many important contributions to the quality of modern life by aiding in the production of food and fiber, by helping prevent the deterioration of structures, by controlling unwanted or hazardous vegetative growth and disease-carrying or obnoxious organisms, and by providing more aesthetically pleasing vistas. The widespread use of pesticides has, however, brought serious concern that they may cause damage to the environment and to humans. The extent of these potential adverse impacts are difficult to evaluate because data on the production, distribution and use of pesticides are available only in a very incomplete and inadquate form. A goal of this program has been to help develop information of this kind and to present it in a form that will be useful in evaluating the overall effects of the present manner of using pesticides and of the optional alternative methods. The study approach has been to analyze available information and data on (a) the production, import and export of all pesticides; and (b) their usage in the agricultural sector, in the industrial/commercial/institutional sector, and by agencies of federal, state and local government. Detailed case studies were then made of the production, distribution and use patterns of 25 major pesticides that had been systematically selected to be representative of pesticides in general.

Some general and specific conclusions and recommendations of the study are as follows:

- Governmental authorities that are responsible for regulation of the environmental aspects of pesticides and persons involved in research on these materials have quite inadequate data available on their production, distribution and use. Published data of the U.S. Tariff Commission, the U.S. Department of Agriculture and the Bureau of the Census are incomplete, frequently incongruous, and at times actually misleading. The reasons for these weaknesses arise in part from existing governmental regulations which limit the disclosure of production data given to the government by industry, in part from inadequate record keeping on production and sales, and--in no small way--from the use of older, limited definitions for the word "pesticide" that are inadequate in the present regulatory and environmental contexts.

- EPA should be authorized to collect from the manufacturers reliable data on the annual domestic production and consumption of all pesticides. In addition EPA should develop--to the degree possible--information on the use of all important pesticides according to geographical region (drainage basins, or governmental unit). In lieu of these authoritative statistics, EPA should annually update and publish the best available estimates of the production of all pesticides. These estimates should specify the amount of each pesticide used, and give totals according to chemical class as well as for the pesticide class. Materials flow information--of the type included in this report--should be published periodically for all major pesticides.

- The present system of data collection and reporting focuses primarily on those synthetic organic chemicals that are used for agricultural purposes. It tends to obscure the substantial use of other synthetic organics that have major nonpesticidal applications, many inorganic pesticides, and pesticides that are used in the industrial/commercial areas. The use of pesticides in the industrial/commercial sector is greater than is generally assumed, but agricultural applications are the major consumers of the synthetic organics.

- By far the most important pesticide in terms of the amount used and economic value of this use is creosote, which is used to prevent destruction of wood products by fungi, termites and other pests. Almost as much creosote is used for this purpose annually in the U.S. as the domestic production of all of the synthetic organic pesticides combined. Creosote has been used for this purpose for over 70 years without exhibiting obvious adverse impacts on man or the environment; although studies of its effect have increased recently, economically and environmentally feasible alternatives for its complete use are not available.

- Based on the Tariff Commission's data for the synthetic organic pesticides, herbicides continue to be the fastest growing category in terms of amounts used. The alternatives to herbicide use continue to remain primarily the older labor- or energy-intensive methods and few new biological plant-control methods appear on the horizon. Among the eight intensive-study herbicides (which includes one inorganic) industrial/commercial use accounted for 16.4% and agriculture 78.4% of the total. The next largest group among the synthetic organics is the insecticides, according to Tariff Commission data (which includes some but not nearly all fumigants). The insecticides are used primarily in agriculture, but with substantial use in both the home and garden area, the industrial/commercial area, and in some cases for public health. This is the one class of pesticides for which nonchemical substitutes appear to be promising, but few economically competitive products or methods are currently available to the users. Fungicides continue to show little overall growth and little indication is seen that biological methods or integrated pest management methods will replace the current applications of fungicidal chemicals--which are largely used in preventive modes.

- The insecticides as a group have the highest acute mammalian toxicities (followed by fungicides and herbicides). They probably have also the greatest potential for adverse environmental impacts, although the wide-scale use of selective herbicides can have long-range consequences on ecosystems. The use of persistent insecticides where they are not essential has decreased somewhat in recent years--particularly with the decreased use of DDT--but in some cases they have been replaced by more toxic materials that require more care in their use, or by materials whose environmental effects are less well known.

The 25 pesticides and a summary of this analysis of their production and use are shown in Table I. The individual case studies contain additional information on production processes and formulation, properties, geographical distribution, environmental impacts, and alternative methods of control for each of the 25 pesticides. For many of these pesticides--including some that have been used in large volume for several years--the information that is available on routes and rates of degradation and effects on nontarget organisms (especially the lower aquatic and terrestrial species) is surprisingly limited. Even less is known about the nature, toxicity and persistence of the environmental degradation products or metabolites of many of these pesticides.

TABLE I

PRODUCTION AND DESTINATION OF 25 SELECTED PESTICIDES (Millions of Pounds AI)

	U.S. Production	Imports	Exports	U.S. Use	Industrial/ Commercial	Government	Home and Garden	Agri- cultural	Geographical Region[a/]					
									NE	SE	NC	SC	NW	SW
Insecticides														
Aldrin	13.0	0	0.3	12.7	1.7	Small	Small	11.0	0.3	0.7	11.0	0.5	0.1	0.1
Carbaryl[b/]	53.0	0	28.0	25.0	1.0	1.5	3.5	19.0	2.0	7.9	4.8	3.9	0.9	2.0
Carbofuran	6.0	0	1.0	5.0	Small	Small	Small	5.0	0.1	0.1	4.4	0.2	0.2	
Chlordane[b/]	20.0	0	5.0	15.0	6.5	0.5	5.0	3.0	1.7	1.8	3.4	1.6	0.4	1.1
Diazinon[b/]	12.0	0	5.0	7.0	1.2	0.8	2.0	3.0	0.4	0.8	2.1	0.6	1.1	
Disulfoton	5.0	0	Negligible	5.0	Small	Small	0.1	4.9	0.02	0.32	1.02	2.42	1.22	
Malathion[b/]	24.0	0.2	8.0	16.2	4.0	2.2	5.0	5.0	1.1	3.5	2.5	1.8	1.0	1.3
Methyl Parathion	51.1	1.1	12.5	39.7	Small	Small	Small	39.7	Negligible	5.0	0.1	31.0	0.7	2.9
Parathion	14.0	Small	4.0	10.0	Small	Small	Small	9.9	0.4	1.4	1.8	3.5	2.9	
Toxaphene	76.0	0	18.0	58.0	1.0	Small	Small	57.0	0.2	20.2	1.2	31.7	4.7	
Subtotal[b/]	274.1	1.3	81.8	193.6	15.4	5.0	15.6	157.5	6.22	41.72	32.32	77.22	18.82	
% U.S. use					8%	2.6%	8.1%	81.3%	3.2%	21.5%	16.7%	39.9%	9.7%	
Herbicides														
Alachlor	24.0	0	3.0	21.0	Negligible	Negligible	Negligible	21.0	1.5	0.8	17.4	0.8	0.5	
Atrazine	95.0	Negligible	20.0	75.0	1.7	0.3	1.0	72.0	2.5	5.5	57.3	7.7	2.0	
Bromacil[b/]	4.0	0	1.0	3.0	2.3	0.3	0	0.4	0.2	0.5	0.4	0.8	0.2	0.6
2,4-D[b/]	55.0	Negligible	7.0	48.0	6.0	3.0	3.0	36.0	2.0	4.1	21.1	7.0	7.8	3.0
Diuron[b/]	6.5	0.7	0.5	6.7	3.8	0.4	Negligible	2.5	0.4	1.0	0.6	2.1	0.5	1.7
MSMA[b/]	24.0	Negligible	5.0	19.0	4.0	1.0	1.5	12.5	0.4	2.5	1.4	11.6	0.7	0.9
Sodium Chlorate	400.0	30.0	Negligible	35.0[c/]	19.0	1.0	Negligible	15.0	1.8	4.0	3.6	13.8	2.1	9.7
Trifluralin	21.0	0	4.0	17.0	Small	Negligible	Small	16.8	0.4	2.3	6.5	6.2	1.6	
Subtotal[b/]	629.5	30.7	40.5	224.7	36.8	6.0	5.5	176.2	9.2	20.7	108.3	50.0	31.3	
% U.S. use					16.4%	2.7%	2.4%	78.4%	4.1%	9.2%	48.2%	22.3%	13.8%	
Fungicides and Wood Preservatives														
Captan[d/]	17.0	Negligible	1.0	16.0	Negligible	Negligible	6.0	10.0	3.5	2.0	2.0	0.5	2.0	
Creosote	990.0	160.0	0	972[e/]	970.0	Negligible	Negligible	2.0	165.5	145.3	300.6	185.3	90.15	85.15
Maneb[d/]	12.0	0.1	4.5	7.6	Negligible	Negligible	1.6	6.0	1.8	1.5	1.5	0.3	0.9	
Pentachlorophenol	49.7	0	0.7	49.0	47.5	Negligible	1.5	Negligible	11.0	7.5	13.5	7.5	8.0	
Subtotal	1,068.7	160.1	6.2	1,044.6	1,017.5	-	9.1	18.0	181.8	156.3	317.6	193.6	186.2	
(Subtotal minus creosote)	(78.7)	(0.1)	(6.2)	(72.6)	(47.5)	-	(9.1)	(16)	(16.3)	(11.0)	(17.0)	(8.3)	(10.9[illegible]	
% U.S. use					97.4%	-	0.9%	1.7%	17.4%	15%	30.4%	18.5%	17.8%	
(% U.S. use minus creosote)					(65.4%)	-	(12.5%)	(22.0%)	(22.5%)	(15.2%)	(23.4%)	(11.4%)	(15%)	

TABLE I (Concluded)

Fumigants	U.S. Production	Imports	Exports	U.S. Use	Industrial/ Commercial	Government	Home and Garden	Agri- cultural	Geographical Region[a/] NE	SE	NC	SC	NW	SW
Methyl Bromide	25.0	Negligible	2.0	23.0	14.0	Negligible	Negligible	9.0	1.4	5.2	6.3	3.4	1.0	5.7
p-Dichlorobenzene	72.0	0	10.0	55.0[f/]	14.0	2.0	39.0	Negligible	14.7	9.3	14.4	9.3	2.0	5.3
Subtotal	97.0	-	12.0	78.0	28.0	2.0	39.0	9.0	16.1	14.5	20.7	12.7	14.0	
% U.S. use					35.9%	2.6%	50%	11.5%	20.6%	18.6%	26.5%	16.3%	17.9%	
Tin Compounds[g/]	1.8	Negligible	0.35	1.45	0.8	-	-	0.65	0.23	0.31	0.28	0.30	0.33	
% U.S. use					55.2%	-	-	44.8%	15.8%	21.4%	19.3%	20.7%	22.8%	
Totals:	2,071.1	192.1	140.85	1,542.35	1,098.5	13	69.2	361.35	213.55	233.53	479.20	333.82	250.65	
% Total U.S. use					71%	1%	5%	23%	13.8%	15.1%	31.1%	21.6%	16.2%	
Totals - excluding creosote	1,081.1	32.1	140.85	570.35	128.5	13	69.2	359.35	48.05	88.23	178.60	148 [illegible]	73.35	
% Total U.S. use excluding creosote					23%	2%	12%	63%	8.4%	15.5%	31.3%	26.0%	13.2%	

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a/ See pp. 123-125 for states included in each region. Totals for NW and SW were not estimated separately for some products.

b/ Small amounts of some uses are not included in regional totals.

c/ Total domestic Na Chlorate use is 430 million pounds AI of which only 35 million pounds AI is pesticide use.

d/ Regional figures are for agricultural use only.

e/ Includes only wood preservation use; 178 million pounds AI is burned as fuel.

f/ Includes moth control and lavatory-space deodorant purposes only.

g/ Includes triphenyltin hydroxide (Du-Ter®), tricyclohexyltin hydroxide (Plictran®), and bis(tributyl)tin oxide (TBTO).

III. PESTICIDE PRODUCTION, IMPORTS, EXPORTS, AND DOMESTIC SUPPLIES

A. Introduction

In the U.S., there is no single, authoritative source of information on the production, imports, exports, and domestic uses of all pesticides. Several different federal government agencies as well as a few trade journals[14-29] keep statistics on the production and movements of certain pesticides. In the following sections of this chapter, the characteristics of the available pesticide data sources and their use in this study will be discussed.

B. The USDA "Pesticide Review"

The Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture annually publishes the "Pesticide Review." This publication is probably the most widely used and quoted source of data on pesticides and their production and uses in the United States. It includes data from the U.S. Tariff Commission, the Bureau of Mines, the Bureau of Census, the USDA, possibly other federal government agencies, and other sources. The "Pesticide Review" is usually published about 18 months after the end of the most recent year for which data are included. For example, the "Pesticide Review 1972," the most recent issue available at this writing (February 1974), was published in June of 1973 and includes only preliminary data for 1971. Table II summarizes pesticide production volumes by major categories for the period 1967-1971, from the "Pesticide Review 1972."

C. Organic Pesticides

The most important primary data source on which the USDA's "Pesticide Review" relies is the annual report of the United States Tariff Commission on the "U.S. Production and Sales of Pesticides and Related Products," a part of the Tariff Commission's report on U.S. production and sales of synthetic organic chemicals. The pesticides report is usually issued in preliminary form about 10 months after the end of the year for which pesticide movements are reported. The most recently issued report covers the calendar year 1972 and was published in October of 1973. Data in the Tariff Commission's report are therefore considerably more current than those in the USDA's "Pesticide Review."

The Tariff Commission's pesticide report covers most synthetic organic chemicals; it does not include inorganic pesticides nor all organic pesticides. Pesticide production figures are presented in the Tarriff

TABLE 11

USDA DATA ON PESTICIDE PRODUCTION IN THE UNITED STATES, 1967-1971[15]

Pesticide	1967 (1,000 lb)	1968 (1,000 lb)	1969 (1,000 lb)	1970 (1,000 lb)	1971a/ (1,000 lb)
Fungicides					
Copper naphthenate	3,473	1,718	1,545	1,730	1,695
Copper sulfateb/	33,992	37,192	42,072	28,768	31,112
Dithiocarbamic acid salts	c/	c/	c/	39,381	35,110
Ferbam	2,331	1,900	1,500d/	c/	c/
Nabam	1,361	2,000d/	1,938	c/	c/
Zineb	3,055	3,081	2,500d/	c/	c/
Mercury fungicides	912	1,448	941	1,114	601
Pentachlorophenol (PCP)e/	44,239	48,575	45,988	47,170	50,877
2,4,5-Trichlorophenol and salts	25,254	28,066	c/	c/	c/
Other organic fungicides	63,269	66,793	85,607	50,307f/	60,875
Totalg/	177,886	190,773	182,091	168,470	180,270
Herbicides					
2,4-D acidh/	(77,139)	(79,263)	(47,077)	(43,576)	c/
2,4-D acid, esters, and salts	83,750	94,116	56,998	c/	c/
DNBP, ammonium salts	58	c/	c/	c/	c/
Maleic hydrazide	c/	c/	2,771	3,271	c/
Methanearsonic acid salts	c/	c/	c/	30,454	24,476
Phenyl mercuric acetate (PMA)i/	518	582	534	457	337
Silvex	c/	c/	1,597	2,016	c/
Sodium chloratej/	30,000	30,000	30,000	30,000	30,000
2,4,5-T acidh/	(14,552)	(17,530)	(4,999)	c/	c/
2,4,5-T acid, esters, and salts	27,189	45,542	11,626	12,335	c/
Other organic herbicides	206,759	235,541	268,238	312,132f/	404,036
Total	439,965	499,514	423,840	434,241	458,849
Insecticides, Fumigants, Rodenticidesk/					
Aldrin-toxaphene groupl/	120,183	115,974	107,311	88,641	116,264
Calcium arsenate	2,040f/	3,398	1,158f/	1,144f/	940
DDT	103,411	139,401	123,103	59,316	c/
Dibromochloropropane	5,240	7,887	8,611	c/	c/
Lead arsenate	5,952	9,016	9,204f/	4,156f/	6,168
Methyl bromidem/	19,665	20,454	20,033	21,047	c/
Organophosphorus insecticidesh/	c/	c/	c/	132,496	(138,185)
Methyl parathion	33,344	38,163	50,572	41,353	37,226
Parathion	11,361	20,000d/	c/	15,259	c/
Other	c/	c/	c/	75,884	100,959
Other organic insecticides	202,600	227,326	260,892	188,632	303,261
Total	503,796f/	581,619	580,884f/	495,432f/	564,818
Grand Total	1,029,956f/	1,175,173	1,134,739f/	1,054,567f/	1,203,937

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a/ Preliminary.
b/ Shipments by producers to agriculture (including for use as a minor plant nutrient).
c/ Withheld to avoid disclosure. Figure included in totals.
d/ Estimated.
e/ Not only a wood preservative for wood rot control but also a herbicide and desiccant.
f/ Revised.
g/ Sulfur not included may amount to 150 million pounds.
h/ Figures in parentheses represent duplication but are included in totals to be comparable with the 1971 total.
i/ Also a fungicide.
j/ Estimated shipments to producers of herbicides and defoliants.
k/ Includes a small quantity of synthetic soil conditioners; does not include the fumigants carbon tetrachloride, carbon disulfide, ethylene dibromide, and ethylene dichloride, which have many other uses; nor does it include paradichlorobenzene (classed by the Tariff Commission as an intermediate) or inorganic rodenticides.
l/ Includes aldrin, chlordane, dieldrin, endrin, heptachlor, Strobane (R), and toxaphene.
m/ Fumigant for control of both insects and weeds.
Source: Tariff Commission, Bureau of the Census, Bureau of Mines, and chemical industry.

Commission report under the categories: "benzenoid and nonbenzenoid chemicals" and "fungicides, herbicides, and insecticides." Very few of the major pesticides are accounted for individually; most of them are lumped together into large, general categories. Plant hormones are included among the herbicides. Rodenticides, soil conditioners and fumigants are included among the insecticides. In the report for 1972, the catch-all category "all other acyclic insecticides, rodenticides, soil conditioners and fumigants" alone makes up almost 20% of all organic insecticides. The fungicides category includes large quantities of penta- and trichlorophenol (about 45% of the total).

The Tariff Commission reports do not include data on pesticidal products derived directly from fossil fuels such as coal tar, creosote and petroleum oils (the amount of creosote used annually in wood preservation is nearly as great as that of the over 200 synthetic organic pesticides combined). Nor do they include numerous synthetic organics that have large nonpesticidal uses, such as several fumigants (e.g., dichlorobenzene, carbon disulfide, trichloroethane, carbon tetrachloride, ethylene dibromide, ethylene dichloride and ethylene oxide), several fungicides (e.g., the dithiocarbamates, thiram and ziram; the proprietary dithiocarbamate mixtures, Niacide®, Polyram®, Dithane M-45®, and Manzate 200®), biphenyl, orthophenyl phenol, and organotin compounds. The California pesticide use report (see Appendix B) notes substantial uses of many of these compounds. In addition, the Tariff Commission does not include data on a number of disinfectants, bacteriostats and germicides that are being increasingly considered as pesticides by some other agencies of government.

Table III summarizes U.S. production of synthetic organic pesticides by major categories from the Tariff Commission reports for 1971 and 1972, respectively. The production volume of herbicides increased by 5% from 1971 to 1972; the fungicide volume decreased by 4%, while the insecticide volume increased by 1%. The combined production volume of synthetic organic pesticides increased by 2%.

The Tariff Commission's report includes statistics on pesticide sales (domestic and export) by quantity, value and unit value. However, there is a consistent imbalance between the reported production and sales volumes of synthetic organic pesticides. Table IV summarizes the reported annual figures for production and sales of synthetic organic pesticides for the period 1962-1972. In each of the 11 years, reported production exceeded reported sales by a considerable margin, ranging from 90 million pounds AI in 1964 to 233 million pounds AI in 1968. According to these figures, a cumulative excess of production over sales of 1.64 billion pounds existed during the 11-year period in question. Stocks in inventory, carry-over from one season to the next and similar factors could account for such imbalances between individual years, but these would be expected to even out over a longer period of time. As shown in Table IV, they do not.

TABLE III

U.S. TARIFF COMMISSION TOTALS ON THE PRODUCTION OF SYNTHETIC ORGANIC PESTICIDES, 1971 AND 1972[14]

Type of Pesticide	1,000 lb AI		Increase
	1971	1972	1971/1972
Herbicides[a]	428,512	451,311	5%
Insecticides[b]	557,710	563,575	1%
Fungicides[c]	149,495	142,812	-4%
Totals	1,135,717	1,157,698	2%

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a/ Includes plant growth regulators and defoliants.

b/ Includes miticides, nematicides, rodenticides, fumigants (except p-dichlorobenzene) and soil conditioners.

c/ Excludes o-phenylphenol.

TABLE IV

PRODUCTION VS SALES FOR SYNTHETIC ORGANIC PESTICIDES, UNITED STATES, 1962-1972[14,15]

Year	Production (1,000 lb AI)	Sales (Domestic and Export) (1,000 lb)	Excess of Production over Sales (1,000 lb)
1962	729,718	633,962	95,756
1963	763,477	651,471	112,006
1964	782,749	692,355	90,394
1965	877,197	763,905	113,292
1966	1,013,110	822,256	190,854
1967	1,049,663	897,363	152,300
1968	1,192,360	959,631	232,729
1969	1,104,381	928,663	175,718
1970	1,034,075	880,914	153,161
1971	1,135,717	946,337	189,380
1972	1,157,698	1,021,565	136,133
11 Years Cumulative	10,840,145	9,198,422	1,641,723

In discussing this problem with pesticide experts at the U.S. Tariff Commission, we were advised that, in their opinion, the production figures are more reliable than those on the sales volumes. Producers of pesticide active ingredients (as well as producers of other organic chemicals) usually have very accurate statistics concerning their volumes of production. Reliable statistics concerning sales are difficult to compile because pesticides may be sold as technical active ingredients or as manufacturing concentrates for further processing by others; they may be shipped from the production plant to another facility of the same company for further processing; or they may be formulated into one or more finished, ready-to-use products at the same site and then sold. Pesticide sales are usually accounted for in terms of quantities of the finished product that the manufacturer sells. Often this is not the active ingredient, but one or more formulated products containing different concentrations of active ingredient. Converting these quantities of formulations back into active ingredient may be a considerable source of difficulty and error.

U.S. Tariff Commission pesticide experts furthermore point out that they consider the reported production figures to be minimal. It is not likely that pesticide production figures would be overstated to the Tariff Commission. Conversely, it is quite possible that quantities actually produced would not be included in manufacturers' reports due to oversights and/or errors in data collection.

One case in point is found in the statistics on the production and disposition of DDT during a recent 6-year period. Table V summarizes U.S. production, exports and "domestic disappearance" of DDT as reported in the USDA "Pesticide Review" for the years 1965 through 1970. (1970 is the last year for which DDT is shown individually in these statistics; for subsequent years, DDT is included in a large and diverse category entitled "all other cyclic insecticides and rodenticides" in the U.S. Tariff Commission's pesticide report.)

During the 6-year period shown in Table V, total "disappearance" (domestic uses plus exports) of DDT exceeded total reported production by about 44 million pounds AI. It is not clear whether in this instance, domestic uses and/or exports have been overstated, or production understated. There was a considerable demand for DDT in 1970 and 1971 for intrastate stockpiling in anticipation of the cancellation of the registrations for domestic uses of DDT which was then pending. Thus, the production volume reported for 1970 may be low. On the other hand, the number of DDT producers dropped from five in 1970 to two in 1971, so that production probably was decreasing during 1970 as three producers shut down.

These examples illustrate the possibility that the Tariff Commission's pesticide production figures may be on the low side, at least

TABLE V

U.S. DDT PRODUCTION, EXPORT AND "DOMESTIC DISAPPEARANCE," 1965-1970[16]

(1,000 lb)

Year	Production	Export	"Domestic Disappearance"	Total "Disappearance"	Variance Disappearance/ Production
1965	140,785	90,414	52,986	143,400	+ 2,615
1966	141,349	90,914	45,603	136,517	- 4,832
1967	103,411	81,828	40,257	122,085	+ 18,674
1968	139,401	109,148	32,753	141,901	+ 2,500
1969	123,103	82,078	30,256	112,334	- 10,769
1970	59,316	69,550	25,457	95,007	+ 35,691
1971	[a]				
Totals	707,365	523,932	227,312	751,244	+ 43,879

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[a] DDT production was not shown individually in the pesticide production report after 1970 because less than three producers remained.

in some instances. However, if such underreporting occurs, it would be small in relation to the total quantities involved and it would not change the overall picture appreciably.

D. Inorganic Pesticides

Some statistics on the production of inorganic chemicals are kept by the Bureau of Mines, and estimates on inorganic pesticides derived therefrom are included in the USDA's Pesticide Review each year.

Some important inorganic pesticides reported in the USDA Pesticide Review are copper sulfate, sodium chlorate, calcium arsenate, lead arsenate and others (see Table II, p. 10).

A host of other inorganic pesticides are not included in the USDA Pesticide Review. These include sulfuric and phosphoric acids, sodium arsenate, ammonium sulfamate (AMS), aluminum phosphide, sulfuryl fluoride and cryolite. The California pesticide use report (see Appendix B) notes substantial use of many of these compounds. In addition, the USDA review does not include the chromated wood preservatives in the totals for pesticides.

Inorganic sulfur is also used in substantial quantities for pest control purposes, chiefly for the control of fungus diseases on crops. The USDA Pesticide Review (1972) states that sulfur used for fungicidal purposes "may amount to 150 million pounds." While this quantity is very large compared to most organic or inorganic fungicides, it represents only a small fraction of the total production and consumption of sulfur. For this reason inorganic sulfur is often omitted from statistics on pesticides.

E. Pesticide Imports

Pesticide imports are reported by the Bureau of the Census, (Report FT 246, TSUSA Schedule 405-1500), and by the U.S. Tariff Commission in its annual report on "Imports of Benzenoid Chemicals and Products" (TC Publication 601). The latter report, by its title definition, would include only cyclic organic pesticides, but it actually includes also a few acyclic pesticides such as malathion. The Tariff Commission report is issued annually and usually becomes available about 8 months after the end of the year to which it pertains. The most recent report available covers imports during 1972 and was published in August of 1973.

The pesticide import data in the Tariff Commission report are reported differently from the data on domestic production; the domestic data are categorized by both active ingredients and formulated products but the import data do not make this distinction. However, our experience, and that of several pesticide importers with whom we checked, indicate that practically all pesticides imported into the United States are imported as active ingredient. Thus, we have made no adjustments for possibly lower active ingredient content of formulations in using the pesticide import figures.

The Tariff Commission's report for 1972 provides detailed data, by chemical, for imports of benzenoid pesticides totalling 21.6 million pounds. Unspecified "other pesticides" make up an additional 82,070 lb. The report states that the total shown, 21.7 million pounds, amounted to 92% of the total quantity of pesticides imported according to the statistics of the Bureau of the Census, U.S. Department of Commerce. Thus the true total for all pesticides would appear to be 23.6 million pounds, i.e., almost 2 million pounds higher than the Tariff Commission's total.

Another incongruity between Tariff Commission import statistics and other statistics on pesticides is that the former include some disinfectants that are not included among pesticides in the USDA's Pesticide Review (Section B above) or the Tariff Commission's pesticide production report (Section C above). Imports of disinfectants and related products included in the pesticide total amount to about 500,000 lb. Deducting this quantity from the total, we estimate that imports of benzenoid pesticides in 1972 were about 23.0 million pounds.

Our search failed to produce any records or indications of imports of inorganic pesticides into the U.S.

F. Pesticide Exports

Pesticide exports are reported by the Bureau of the Census in its annual report (FT 410). This report records exports of pesticides (by quantity and by value) by "organic pesticide active ingredients," "inorganic pesticide active ingredients," and "formulated pesticides" (the latter not categorized according to organic and inorganic active ingredients). There are several subcategories in each of these three major classes, but in most cases data are not reported concerning individual products.

The census report includes among pesticides certain disinfectants, deodorants and germicides which are not classed as pesticides in other statistics. It also includes inorganic sulfur fungicides which are likewise not included in many other statistics on pesticides, as was pointed out in Section D.

A further problem is the fact that in the category of formulated pesticides, quantities are reported only in terms of the finished, formulated products, without indication of the active ingredient content.

In order to translate these totals into quantities of active ingredients, we made a thorough analysis of census data for all pesticide exports recorded in Schedules 599.2010 through .2090, comprising "insecticides, fungicides, disinfectants and similar products as separate, chemically defined compounds put up in forms or packings for retail sale; or preparations (mixtures), whether put up in bulk or for retail sale." For each pesticide category in this schedule (including herbicides), unit dollar values of the pesticide exports were computed by countries of destination. Based on our knowledge of the crop protection problems and/or the pesticide trading patterns of the countries of destination, and the costs of different pesticide products, we estimated exports by products and active ingredient contents for the major pesticides in each category. Appropriate correction factors were then applied to convert the quantities of formulated pesticides exported into active ingredient equivalents. These were then added to the quantities of pesticides exported as active ingredients as reported in commodity groups 512.0610 through .0685, and 514.7035 through .7045 of report FT 410. The estimated export for each of the 25 intensive-study pesticides are included in the individual case studies.

G. Domestic Supplies of Pesticides

Our estimate of the domestic supply of pesticides in 1972 is summarized in Table VI. In this table, we elected to separate soil conditioners and fumigants from insecticides. Soil conditioners and to a lesser extent most fumigants have little in common with insecticides in regard to their physical, chemical, and biological properties, and their use patterns. They are often included in the insecticide category simply because this is the way the Tariff Commission's report on synthetic organic chemicals (Section C above) treats them.

Furthermore, we have separated penta- and trichlorophenols from fungicides. These chlorinated phenols account for almost one-half of the quantity of all organic fungicides. Again, their properties and use patterns differ greatly from those of most other fungicides and, in our opinion, these two types of fungicides deserve separate discussion and consideration.

Furthermore, we have separated the herbicide, insecticide and fungicide categories into organic and inorganic chemicals, as well as showing combined inorganic plus organic subtotals and totals for all pesticides.

TABLE VI

ESTIMATED PRODUCTION, IMPORTS, EXPORTS AND DOMESTIC SUPPLIES OF SELECTED PESTICIDES BY CATEGORIES, 1972

	U.S. Production	Imports	Exports	Domestic Supply
Herbicides[a]				
Organic	451,300	12,200	76,400	387,100
Inorganic	41,000	Negligible	400	40,600
Subtotal	492,300	12,200	76,800	427,700
Insecticides[b]				
Organic	442,700	5,600	174,900	273,400
Inorganic	7,000	Negligible	1,600	5,400
Subtotal	449,700	5,600	176,500	278,800
Fungicides[c]				
Organic	83,000	5,200	24,000	64,200
Inorganic	60,000	Negligible	5,300	54,700
Subtotal	143,000	5,200	29,300	118,900
Fumigants,[d] Soil Conditioners	121,000	Negligible	38,900	82,100
Penta- and Tri-Cl-Phenols	70,000	Negligible	1,500	68,500
All Pesticides[e]				
Organic	1,168,000	23,000	315,700	875,300
Inorganic	108,000	Negligible	7,300	100,700
Totals	1,276,000	23,000	323,000	976,000

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[a] Includes defoliants, desiccants, plant growth regulators, chlorates.

[b] Includes miticides, nematicides, rodenticides, repellents.

[c] Excludes sulfur, creosote, coal tar, penta- and trichlorophenols.

[d] Excludes p-dichlorobenzene and certain other fumigants (see p. 11).

[e] Excludes sulfur, creosote, petroleum, coal tar, p-dichlorobenzene, etc. (see pp. 11 and 16).

Our final estimates for U.S. production, imports and exports were obtained by following the steps and making the adjustments outlined in Sections E and F above. Imports were then added to, and exports subtracted from the appropriate U.S. production categories to obtain domestic supplies.

Our estimates as shown in Table VI are at variance with the Tariff Commission's preliminary data on the production of synthetic organic pesticides in 1972 on one point. The Tariff Commission's total for the production of cyclic fungicides, 98,164,000 lb, includes 49,704,000 lb of pentachlorophenol. Trichlorophenol is not shown separately in the 1972 report, but is included in the category "all other cyclic fungicides" which totals 45,360,000 lb. Up until 1968, trichlorophenols (and their salts) were shown separately within the cyclic fungicides group. Their reported production volume was 25,254,000 lb in 1967; 28,066,000 lb in 1968 (Table II). Assuming (conservatively) that the production of trichlorophenol and salts for pesticidal purposes in 1972 was at least 20,000,000 lb, the resulting balance, which all cyclic fungicides other than tri- and pentachlorophenol would have to share, would be only about 28,000,000 lb. Our estimates indicate that such an assumption would be unrealistic, and that the volume of production of cyclic fungicides other than tri- and pentachlorophenol in 1972 was about 38,000,000 lb. Accordingly, our estimates for the 1972 production of organic fungicides including penta- and trichlorophenols exceed those reported by the Tariff Commission by 10,000,000 lb. This difference is carried forward to the totals for all organic pesticides and for all pesticides, our estimates being higher by the same 10,000,000 lb in each case.

Trichlorophenol is also used as reactive intermediate (e.g., in making 2,4,5-T). Part, but not all, of production for this purpose is probably included in the Tariff Commission's data for fungicides. This factor may account for the major part of the discrepancy.

A second factor may explain this and several other, smaller apparent inconsistencies between different statistics and different estimates on the production and movements of pesticides: substantial differences may occur between pesticide inventories at the beginning and at the end of the reporting year. This factor may operate particularly in the case of several smaller-volume pesticides. In such cases, one production run sometimes suffices for two or more seasons of use. Such a product would then appear in the production statistics only in the year when it was made, while its use in the field would proceed at a more even annual rate. Our data indicate that in general, pesticide stocks in inventory at the beginning of 1972 were sufficiently similar to those on hand at the end of the year that this factor would not appreciably affect the overall picture. This problem does not appear to be a major factor with any of our intensive-study products in 1972, nor a sifnificant problem in the remaining pesticides as a group.

H. Estimated Production, Imports, Exports and Uses of the Intensive-Study Pesticides

Estimates of the production volumes, imports, exports, and domestic uses of the 25 intensive-study pesticides were arrived at by a careful, step-wise procedure of analyzing, cross-checking and correlating different information items, including all published data and statistics mentioned in the preceding sections of this chapter. In addition, numerous news items in trade magazines and other pesticide-related literature were studied and utilized where appropriate. Initial estimates were prepared and reevaluated with the assistance of other pesticide experts, and with the generous cooperation of many of the basic producers of the products involved.

We believe these estimates to be accurate within a tolerance limit of ± 10% for quantities over 10 million pounds, and to ± 1 million pounds for volumes below 10 million pounds, except where stated otherwise.

Home and garden uses of pesticides were not included in the scope of this study. Little data are available on the kinds and quantities of pesticides that are used in this area in the U.S.[2/] Our estimates on the quantities of the selected study products used in the home and garden sector were obtained simply by subtracting the estimated volumes of use in the other three categories from the estimated domestic supply. Unlike the other estimates, home and garden use estimates are not supported by any other survey results or statistics.

Pesticide uses in the other three major categories are discussed in detail in Chapters IV, V, and VI of this report.

IV. AGRICULTURAL USES OF PESTICIDES

A. Introduction

Chemical pesticides including insecticides, miticides, nematicides, rodenticides, fungicides, fumigants, herbicides, plant growth regulators, defoliants, desiccants, and others are used extensively by American farmers for the protection of crops, rangeland, livestock, stored products and structures from pests. Modern agricultural production techniques such as growing large, continuous stands of one crop (monoculture), use of high yielding crop varieties, irrigation, fertilizers, etc., increase potential crop losses due to pests and thus the need to prevent such losses. American farmers use high levels of production inputs (including capital, power, and those mentioned in the preceding sentence) per unit of cropland. Thus, a growing crop often represents a substantial investment. If and when that investment becomes exposed to potential pest damage, there is a powerful incentive to protect it.

According to the U.S. Department of Agriculture (1970, 1974), farmers used 52% of all pesticides used in the U.S. in 1966, 59% in 1971. Table VII summarizes total domestic use* and farm use of pesticides in 1966 compared to 1971 according to these USDA estimates.

Total U.S. use of herbicides increased from 227 to 359 million pounds of active ingredients from 1966 to 1971 (58% increase). During the same time, farm use of herbicides increased by slightly over 100%, increasing farmers' share of the total domestic use of herbicides from 55% in 1966 to 70% in 1971.

According to the same sources, the total domestic use of insecticides decreased by 3% from 1966 to 1971, i.e., from 329 to 319 million pounds of active ingredients. Farm use of insecticides increased slightly (3%) from 1966 to 1971, i.e., from 195 to 201 million pounds of active ingredients. Farmers' share of the total U.S. use of insecticides increased from 59% in 1966 to 63% in 1971.

Total fungicide use in the U.S. increased by 24% from 1966 to 1971, i.e., from 125 to 155 million pounds of active ingredients. Farm use of fungicides increased at about the same rate (27%), from 33 to 42 million pounds of active ingredients. Farmers' share of the total domestic use of fungicides was about the same in 1971 (27%) as in 1966 (26%).

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* Note that the totals given in Table VII differ substantially from the totals given in Tables II and III which are for production, not consumption.

TABLE VII

USDA ESTIMATES OF PERCENTAGES OF PESTICIDES USED BY FARMERS IN THE UNITED STATES, IN 1966 AND 1971[17,18]

	Total U.S. Use (1,000,000 lb AI)			Farm Use (1,000,000 lb AI)			Farmers' Share of Total Use	
Type of Pesticide[a]	1966	1971	Increase 1966-1971	1966	1971	Increase 1966-1971	1966	1971
Herbicides	227	359	58%	125	251	101%	55%	70%
Insecticides	329	319	-3%	195	201	3%	59%	63%
Fungicides	125	155	24%	33	42	27%	26%	27%
Totals	681	833	22%	353	494	40%	52%	59%

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[a] Herbicides include plant growth regulators, defoliants, desiccants; insecticides include miticides, rodenticides, fumigants; excluded are sulfur, creosote, petroleum oils and several other pesticides as discussed on pp. 11 and 16.

According to the USDA estimates, the domestic use of pesticides for all purposes increased from 681 to 833 million pounds of active ingredients from 1966 to 1971 (22%). Farm use of pesticides increased by 40%, from 353 to 494 million pounds of active ingredients. This increase in farmers' share of the total domestic use of pesticides is primarily due to the increased use of chemical herbicides in agriculture.

Farm uses of pesticides are highly concentrated, i.e., only a small number of crops account for 80 to 90% of all agricultural uses of herbicides, insecticides and fungicides, respectively.

Herbicides (including defoliants, desiccants and plant growth regulators): We estimate that at the present time, more than 90% of all herbicides used by American farmers go on field crops. Three crops account for close to 80% of the total farm consumption of herbicides, i.e., corn (about 50%), soybeans (17%), and cotton (11%). Wheat and sorghum account for an estimated 5% each of total farm herbicide use, while rice, peanuts and several minor crops make up the balance of field crop uses. Less than 10% of all herbicides used in agriculture go on pasture and rangeland, vegetables, fruits and nuts, and fallow land.

Insecticides (including miticides and rodenticides, excluding fumigants): More than 80% of the total quantity of insecticides used by farmers in the U.S. at present are applied to field crops. Only two crops account for almost 70% of this total, i.e., cotton (close to 50%) and corn (18%). Soybeans, tobacco and a number of other crops account for the remaining insecticide uses on field crops. Fruit and nut crops (including citrus) receive approximately 10% of the insecticides used in agriculture, whereas vegetable crops, pastures and a number of minor other crops account for the balance.

Fungicides (excluding sulfur, creosote, wood preservatives): Approximately 60% of all fungicides currently used in agriculture in the United States are applied to fruit and nut crops, including citrus fruits. About 25% of agricultural fungicides go on vegetables, the balance of about 15% on field crops.

Table VIII presents an overview of the major farm uses of the pesticides selected for special study in this project. It is evident that the study products cover all major farm uses of pesticides.

In the following sections of this chapter, the sources of information that form the basis for our estimates of the agricultural uses of the 25 study products will be discussed. Data and information from all of the sources detailed below in Sections B through F were systematically collected, analyzed, cross-checked, and condensed into an initial scope estimate for

TABLE VIII

MAJOR AGRICULTURAL USES OF INTENSIVE-STUDY PESTICIDES BY CROP AND TYPE

Crop	Herbicides	Insecticides	Fungicides
Corn	Alachlor Atrazine 2,4-D	Aldrin Carbaryl Carbofuran Chlordane Diazinon Disulfoton Parathion Toxaphene	Captan[a]
Soybeans	Alachlor Trifluralin	Carbaryl Malathion Me-parathion Toxaphene	Captan[a]
Cotton	Alachlor Diuron MSMA Trifluralin	Carbaryl Disulfoton Malathion Parathion Me-parathion Toxaphene	Captan[a]
Sorghum, Small grains	2,4-D	Disulfoton Parathion Toxaphene	Captan[a] Maneb[a]
Fruit crops (including citrus, pineapples)	Atrazine Bromacil Diuron	Carbaryl Diazinon Malathion Parathion Plictran®	Captan Maneb
Vegetable crops	Diuron Trifluralin	Carbaryl Diazinon Malathion Parathion	Captan Maneb

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[a] Seed protection.

each study product. These preliminary estimates were then subjected to scrutiny by other project members; outside consultants and other experts; pesticide manufacturers, formulators, distributors and retailers; and federal, state and university pesticide experts. They were further refined as additional data were obtained. Information gathering activities in this phase of the project included field trips to Arizona, Delaware, Iowa, Illinois, North Carolina, Pennsylvania, and Texas, several trips to Washington, D.C., plus extensive telephone contacts with experts in other areas. The estimates of the agricultural uses of each study product by quantities and geographic regions were eventually finalized by correlation and integration of all of these numerous and diverse inputs. These estimates are presented in the individual case studies, and they are reflected in the flow diagrams for each study product (see Section VIII of this report).

B. The USDA Farm Pesticide Use Reports

The USDA reports on the "Quantities of Pesticides Used by Farmers" in 1966 and 1971, cited above, are the most comprehensive sources of nationwide information in this field. When our study was initiated early in 1973, we were aware of the USDA's 1971 survey. Our desire to make use of their survey results to the greatest extent possible received the Department's full cooperation. The Economic Research Service's National Economic Analysis Division made available to us a set of raw data from their survey in the summer of 1973, and a copy of the manuscript of their complete report was received in time for the completion of the present chapter of our report. The U.S. Department of Agriculture's cooperation was very helpful and is gratefully acknowledged. The data from their survey are an important addition to those we obtained from other sources, even though they pertain to 1971, while the base year for our study is 1972.

Our estimates of the quantities of the 25 intensive-study pesticides that were used by farmers in the United States in 1972 differ considerably from those reported by the USDA for 1971 for a number of products. In our analysis, some of these differences reflect actual changes in pesticide use patterns from 1971 to 1972. For instance, several different information sources confirm independently that the use of methyl parathion and toxaphene on field crops, especially on cotton and soybeans, increased significantly from 1971 to 1972. Likewise, the use of alachlor herbicide increased substantially from 1971 to 1972. By contrast, differences between the two surveys in the estimated farm use of several other pesticides (examples: atrazine, MSMA) appear to be due to other reasons. In the case of 2,4-D, aldrin, carbaryl, parathion, and diazinon, there are no indications of major changes in use patterns from 1971 to 1972, and the two surveys are in reasonably good agreement.

The basic data for the USDA's 1971 farm pesticide survey were obtained from personal interviews with about 8,600 farmers in 394 counties throughout the United States (except Alaska). These interviews were conducted in a nationwide program whose principal purpose was to obtain data on farm production expenditures for 1971. The original, raw pesticide data were then expanded and adjusted by specific factors to translate them from the survey sample to the national universe.

The questionnaire used in this survey, entitled "1971 Farm Production Expenditure Survey" (USDA Statistical Reporting Service, OMB #40-S71102), is a mammoth form, consisting of 56 pages and 487 questions, many including numerous subquestions. Reportedly, completion of one interview takes a minimum of 3 hr. (Persons knowledgable in conducting personal farmer interviews feel that the productive cooperation span of farmers in such situations rarely exceeds 30 min.)

In this questionnaire, 28 of the 487 master questions pertain to pesticides. An analysis of the format provided for pesticide use entries suggests that even a person highly trained in the field of pesticides, and being familiar with the many different brands, formulations, concentrations and package sizes in which pesticides are available, and the different ways in which they are applied, would have difficulty completing the form accurately.

As an example, a given corn field may be treated by a single herbicide or by a mixture of several herbicides, applied preemergence either as a broadcast or as a band treatment; this preemergence application may be followed by one or more postemergence applications of a single herbicide or a mixture of several products. The same field may also receive pre- and/or postemergence broadcast, band, or in-furrow treatments of one or more insecticides or combinations. The corn seed planted may have been treated with one or more seed protectant fungicide(s) and/or insecticide(s). These treatments can be applied to the seed either prior to planting (by the seed house, a commercial seed treating establishment, or by the farmer himself), or by way of a planter box treatment. The same corn field could also receive one or more foliar fungicide treatment for the control of foliar diseases, and/or foliar insecticide treatment(s).

Pesticide use patterns on many other crops are equally or even more complex. All of these intricate details are being asked of and by people who are generally not pesticide experts. Furthermore, the entire pesticide section represents only a small portion of all questions in the lengthy survey form. Thus, it is not surprising that the data on the quantities of pesticides used by farmers obtained by extrapolation from this source are in some points at variance with pesticide use data from other sources.

An excellent discussion of the difficulties involved in arriving at meaningful pesticide use data has been presented by Petty (1974).[35] This investigator compared data on the use of pesticides in Illinois obtained from (1) a survey of county extension advisors; (2) random surveys of 116 to 175 corn fields from 14 to 21 of the 99 counties in Illinois, and (3) from an annual survey of pesticide use conducted by the Illinois Crop Reporting Service. The results from the three separate surveys were quite comparable, with only a few significant discrepancies that were accounted for by sampling methods and sample size.

The smallest geographical unit shown individually in the USDA survey is a "farm production region." Illinois is one of five states included in the "corn belt." Therefore, a direct comparison between the USDA's findings for Illinois and the data in Petty's study is not possible. Likewise, comparisons between the USDA data and those from other individual states that published farm pesticide use data for 1971 (California, Minnesota, Michigan, and Wisconsin) could not be made.

There is one additional major variance between our estimates for 1972 and those in the 1971 USDA survey. The latter pegs the total use of pesticides for all purposes in the U.S. in 1971 at 833 million pounds. According to our estimates (Table VI, p. 19), the comparable figure for 1972 is 976 million pounds. There were no increases of this magnitude in the volume of production of pesticides from 1971 to 1972 (Table III, p. 12), nor in the volume of imports, nor decreases in the volume of exports that could account for a variance of about 140 million pounds. The USDA estimate of the total domestic consumption of pesticides in 1971 is probably too low.

C. Survey of the Federal/State Cooperative Extension Service

The Federal/State Cooperative Extension Service in most states issues recommendations or suggestions on the use of pesticides. A number of extension specialists follow use patterns of agricultural pesticides. We therefore conducted a nationwide survey aimed at collecting all available data on pesticide uses from this source.

In June of 1973, personal letters were written to the Directors of the Cooperative Extension Service in each of the 50 states, and Puerto Rico. We informed them of the purpose of our study and asked for the following three items:

- A complete set of the state's recommendations for the control of insects, weeds, diseases and other pests affecting agricultural crops, fruits, vegetables, ornamentals, forests, home and garden, livestock; and recommendations involving industrial, commercial, public health and other uses of chemical pesticides.

- Copies of reports or studies on actual pesticide use within the state, or any information on agencies or individuals that might keep such records, so that we could contact them directly.

- Information on whether or not the state has a chemical pesticide coordinator.

Reminders were sent to those states that did not reply to the first inquiry and, after considerable follow-up activity in a number of instances, we eventually obtained responses from all but three states (Rhode Island, New Jersey, Nevada). A response was also received from Puerto Rico.

The responses received in regard to the above three items may be summarized as follows.

1. Pesticide use recommendations: A voluminous file of state pesticide use recommendations was accumulated. All 47 states that responded and Puerto Rico furnished us their recommendations. In some instances, several neighboring states jointly develop and use the same recommendations. All recommendations were analyzed thoroughly and proved helpful to the objectives of our study, particularly in two areas, i.e., (1) determining rates of application of study products, to supplement use data furnished us in terms of number of acres treated; and (2) determining chemical and nonchemical alternatives available to specific pesticide uses pertinent to our study.

2. Pesticide use data from state sources: On this question, a number of Extension Service Directors or their representatives advised us that no such data are kept within the state. Others referred us to other departments or individual researchers within the state university, or to other agencies within the state. All of these leads were followed up, and a great volume of correspondence ensued. The results may be summarized as follows:

Comprehensive pesticide use data for 1972 were obtained from California, Illinois, and Minnesota.

Comprehensive data for 1971, and/or partial data for 1972 were obtained from Arizona, Arkansas, Colorado, Florida, Indiana, Iowa, Kansas, Kentucky, Michigan, Mississippi, Montana, New Hampshire, North Carolina, North Dakota, South Carolina, South Dakota, Tennessee, Utah, and Wisconsin.

No pesticide use data were obtained from Alabama, Alaska, Connecticut, Delaware, Georgia, Hawaii, Idaho, Louisiana, Maine, Maryland, Massachusetts, Missouri, Nebraska, Nevada, New Jersey, New Mexico, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Vermont, Virginia, Washington, West Virginia, and Wyoming, nor from Puerto Rico.

3. Statewide Chemical Pesticide Coordinator: Most of the states reported that they have this office and gave us the name of the present officeholder. The following four states reported that they do not have a chemical pesticide coordinator: Hawaii, Kentucky, Michigan, and Washington.

A copy of the letter by which this survey was initiated, and the names of all individuals with whom we communicated by letter, telephone and/or in person in this phase of the study are included in Appendix C of this report. The list comprises 142 names.

D. Survey of the EPA Community Pesticide Studies Projects

In the EPA Community Pesticide Studies Program (now called "Epidemiologic Studies"), pesticide use data for individual states or regions were collected. Through the cooperation of Dr. W. S. Murray, EPA Office of Pesticide Programs, we obtained the names and addresses of 13 Pesticide Community Studies Project Directors. In October of 1973, letters were addressed personally to 10 of these (data from the Pesticide Community Studies in Arizona, California and Utah were already in our files) asking them for any pesticide use data by products, quantities, crops or other end uses that might have been collected in their community pesticide studies. We advised them that 1972 was the base year for our study, but indicated that if they did not have data for that year, information for any other recent time period would also be helpful.

Pesticide use data that added significantly in our study were from the following Pesticide Community Studies Projects: Arizona, Hawaii, Idaho, Mississippi, South Carolina, Texas, and Utah. Three other community pesticides study projects had pesticide use data only for small geographic areas (such as one or two counties) that were interesting in themselves, but did not help our survey significantly. These were: Colorado, Iowa, and Michigan. Data from these studies are presented in Appendix B together with additional data from other sources on pesticide use in other states.

A copy of the letter by which this survey was initiated, and the names of the individuals with whom we were in contact by letter, telephone and/or in person in this phase of the study are included in Appendix D of this report.

E. Survey of Pesticide Manufacturers

The 25 intensive-study products investigated in this project are manufactured by at least 26 basic producers in the U.S.

Products that are made by only one basic producer are as follows:

alachlor
atrazine
bromacil
diuron
trifluralin
aldrin
carbaryl
carbofuran
chlordane
diazinon
disulfoton
malathion
tricyclohexyltin hydroxide
captan
triphenatin hydroxide
bis(tributyltin)oxide

The following products are manufactured by more than one basic producer:

sodium chlorate
2,4-D
MSMA
parathion
methyl parathion
toxaphene
creosote
p-dichlorobenzene
maneb
methyl bromide
pentachlorophenol

Letters were sent to each of the 26 companies who produce one or more of the above products. Most of these letters were addressed personally to an appropriate executive within the company. A copy of this correspondence was sent to the National Agricultural Chemicals Association in Washington, D.C. for information purposes.

Manufacturers were asked to furnish the following data on their respective products:

Physical and chemical properties
Mammalian toxicity and hazards to humans
Toxicity and hazards to nontarget organisms
Hazards to the environment
Degradation in the environment
Principal target crops
Principal target pests
Application equipment, rates, timing and frequency
Areas of use by six major geographic regions.

The cooperation received from the great majority of these companies was excellent. Most of them furnished extensive data on their respective products, including technical bulletins, sample labels, and many other pertinent information items. Some companies were reluctant to comment on the use patterns of their products, but others answered all questions freely.

A number of the same companies were visited in person in the course of another task of this project, as described in greater detail in Chapter II of this report. In these personal meetings, many manufacturers assisted us further in rounding out the information on their products.

The data received from the pesticide producers through these written and personal communications were especially helpful in completing our knowledge in regard to the physical, chemical and biological properties of the study products, their most commonly used formulations, their mammalian toxicity, environmental impact potential, and their use patterns in terms of crops, pests, and geographical distribution.

A copy of the letter sent to the manufacturers and the names of all individuals with whom we communicated by letter, telephone, and/or in person in this phase of the project are included in Appendix E of this report. This list consists of 54 names.

F. Pesticide Data from Other Sources

Several other organizations and individuals recently studied farm pesticide uses. These sources, and other references consulted frequently in this phase of the study are numerous.[4,30-36]

V. INDUSTRIAL, COMMERCIAL, AND INSTITUTIONAL USES OF PESTICIDES

Pesticides are widely used by industrial, commercial, and institutional establishments, but this usage has been studied much less than has agricultural use. This chapter is divided into three main sections: (1) types of pest control problems, (2) major applications of pesticides, and (3) discussions of the usage of 25 intensive-study selected pesticides.

A. Types of Pest Control Problems

The pest control problems confronting the industrial, commercial, and institutional sectors will be discussed separately.

1. Industrial: The large and diverse industrial sector encounters many types of pest problems. Primary concern centers around the control of unwanted vegetation, insects, and vertebrates, and the destruction of property by fungi, mold, etc. A wide variety of herbicides, insecticides, rodenticides, fungicides, and fumigants are used.

Vegetation control takes two forms: (1) controlling weeds, and (2) eliminating vegetation entirely. Weed control is employed in landscaping at industrial plant sites and industrial parks. Weeds are also controlled at refineries, in lumber yards, around warehouses, along fence lines, in ditchbanks, in forest tree nurseries, along roads, utility rights-of-way, and commercial forest lands. Eliminating vegetation entirely (soil sterilization) is often desirable in parking lots, railroad rights-of-way, industrial waste areas, vacant lots, unpaved roads, and around quarry pits.

Insect control is practiced by almost all industrial firms to control nuisance insects indoors (such as termites, roaches, ants, and spiders) and to some degree outdoors (mosquitos around water areas and landscape insect pests) at production facilities. Commercial forests, greenhouses, and nurseries require constant control to maintain their products. The food and beverage industry is much concerned about insect destruction or infestation of its products. Food processors, packagers, bottlers, bakers, brewers, dairies, mills, etc., maintain constant control of insects. The storage of food in warehouses creates a control need pest also: direct application of insecticides or fumigation of enclosed areas is usually employed.

Vertebrate control primarily involves commensal rodents (e.g., Norway rats and house mice) which consume and contaminate foodstuff, and do damage to many objects by gnawing. The consumption of food products by rodents is a problem in nearly all phases of food processing, and is particularly serious in milling and storing cereal grains and products. In their quest for food, rodents can gnaw through almost any material less hard than their tooth enamel, e.g. corrugated boxes, wooden doors, and occasionally even concrete before it has hardened. Gnawing on furniture, lead pipes, plastics, and electrical wiring are frequent activities among rodents. The shipping industry has a particular problem with rats invading ships' holds. In addition, moles, squirrels, bats and gophers are often destructive pests.

Birds create pest problems in industrial areas as well as in agriculture. Birds consume or destroy foodstuffs, carry diseases affecting man, cause economic losses (nonfoodstuffs), and can have negative effects on man's comfort and aesthetics. Birds can enter through broken windows of warehouses and foul stored foodstuffs with droppings or excess nesting material. Bird populations at industrial sites present a hazard to employees since birds produce aerosols and excretions of disease organisms, act as intermediate hosts for infectious disease, and are reservoirs for disease organisms. Economic losses in industry are suffered from birds, also. Power companies are plagued by woodpeckers damaging utility poles, and short circuits caused by birds nesting on poles, flying into wires, perching on wires, or by shorting wires with streams of excrement. Excessive bird populations in industrial areas also create noise problems and are a general nuisance to employees.

Fungus, yeast and molds create problems throughout industry. Mildew-proofing and antifouling paints are used to protect susceptible surfaces. Fungicides are used in industrial cooling waters, food packaging containers, plastic pipes, and many other areas where mildew and fungus are a problem.

Control of the various pests is done by commercial pest control operators, lawn and tree services, or the industrial firm itself. When a firm does not employ the services of outsiders, they usually buy their chemicals from chemical or janitorial supply houses.

2. Commerical: Commercial firms have essentially the same problems as do industrial firms. They too must control unwanted vegetation, insects, vertebrates, and fungus problems. A wide variety of chemicals are used in this sector, also.

Vegetation control involves prevention of weeds in landscaping around buildings such as apartment houses, motels, hotels, restaurants, and warehouses. Soil sterilization is employed in parking lots, unpaved driveways, and fence lines. Firms engaged in enterprises directly producing vegetation, such as sod farms, real estate development, botanical gardens, florists, and herbariums use large amounts of herbicides in the course of their business. Firms engaged in businesses conducted outdoors such as race tracks, drive-in theaters, resort hotels, tennis clubs, summer camps, cemeteries, golf courses, zoological gardens, airports, and marinas use the largest amounts of herbicides in the commercial sector.

Insect control is often a must in commercial establishments because of state and local laws. Food handling firms such as bars, restaurants, grocery stores, meat markets, and outdoor food markets must maintain constant insect control. Firms directly producing vegetation (e.g. sod farms, florists and nurserymen, etc.) also must control insects. All commercial indoor establishments can have insect problems which are either pretreated on a periodic schedule or attacked when an infestation occurs. Those handling food and vegetation represent the largest group of insecticide users.

The vertebrate, bird, and fungus problems encountered in the commercial sector are similar to those previously discussed in the industiral sector. One problem worth specific mention is the control of birds around airports. The possibility of birds striking flying aircraft is an acute danger to man's safety. Bird strikes have caused crashes of airplanes both during take-off and landing.

3. Institutional: Use of pesticides by the institutional sector is small in comparison to the industrial and commercial sectors. Institutions include homes for the aged, blind, orphans, deaf and dumb; private grade schools, high schools, and colleges; churches; private hospitals; tax-exempt charitable foundations; museums; and other nonprofit organizations. Pest control is incidental to the normal functioning of the organization, and primarily involves landscaping and control of nuisance pests indoors.

Hospitals have the most important pest control needs. Control of all insects, vertebrates, and fungus, as well as bacteria and virus, is essential to providing the healthy environment hospitals require. The operating rooms are a very critical area and must be constantly maintained.

Most institutional pest control is contracted to pest control operators, and lawn and garden services. The remainder is done by the institution itself by purchasing the necessary chemicals from chemical or janitorial supply houses. Hospitals do much of their own work since a constant program must be maintained.

B. Major Applications of Pesticides

Industrial, commercial and institutional establishments use herbicides to control unwanted vegetation, insecticides to control destructive pests; fungicides and wood preservatives to protect property; and fumigants to control destructive pests and disease. In this section 11 major categories of pesticide users in the industrial/commercial/institutional sector are discussed. In addition to these specific categories, herbicides are used for general maintenance of grounds. Table IX shows the market for herbicides in this usage, as estimated by Dr. Dale W. Young, an MRI consultant on this project.

1. The wood preservation industry: The wood preservation industry* in the United States has developed because of the need for prolonging the life of wooden structural members mostly where contact with the ground is intended. Wood is preserved by the injection of a variety of chemicals which have fungicidal, insecticidal and fire retardant properties. Historically, railroad ties, telephone poles, and marine pilings treated with creosote have been the major products of the industry. In recent years, lumber and plywood treated with leach-resistant preservative salts have experienced the fastest growth. A listing of the various chemicals used in 1972 and the products produced are presented in Table X.

The wood preservation industry provides the only major use for creosote (other than fuel) and consumes almost a billion pounds of creosote annually (Table XI). About 38 million pounds of pentachlorophenol--almost 80% of the total amount produced--is also consumed in the preservation of wood.

Certain inorganic products containing chromium, copper and arsenic are also used in relatively large quantities for the preservation of wood. As shown in Table XI, the total amount of these products used in wood preservation in 1972 amounted to 13.5 million pounds.

The production of treated wood is very responsive to the general state of the national economy, particularly the health of the construction industry. Production of treated wood decreased slowly, (1.2%) from 1968. to 1971, but increased significantly (1.5%) in 1972. The total value of all preserved wood produced in the United States in 1972 is estimated to be over $450 million.

The volume of wood treated with creosote showed the largest decrease (11%) during the 1968 to 1972 period, and accounted for most of the decrease in total production. Wood treated with pentachlorophenol increased about 14% during the period, while that treated with inorganic preservatives increased about 230%. Production of fire-retardant treated wood remained

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* Mr. Alexander Olisvewski, Technical Director of the American Wood Preservers Institute, has generously provided much helpful information on wood preservation.

TABLE IX

INDUSTRIAL, COMMERCIAL AND INSTITUTIONAL USE OF HERBICIDES FOR GENERAL MAINTENANCE OF GROUNDS[a]

Compound	Rate/Acre (lb)	Acres Treated (thousands)	Total Pounds (thousands)
Chlorate-borate	100	100	10,000
TCA	100	34	3,400
Diuron	6	300	1,800
Ammate	100	10	1,000
MSMA	4	250	1,000
2,4-D	2	500	1,000
Simazine	6	100	600
Bromacil	4	90	360
2,4,5-T	2	100	200
Dalapon	6	30	180
2,4-D and 2,4,5-T	2	90	180
Aminotriazole	2	70	140
Atrazine	6	20	120
Silvex	2	30	60
Krovar	6	10	60
Tandex	4	10	40
Paraquat	0.5	40	20
Tordon	3	6	18
	TOTAL	1,790	20,178

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[a] Source: Dr. Dale W. Young.

TABLE X

WOODEN MATERIALS TREATED IN THE UNITED STATES, BY PRODUCT AND PRESERVATIVE, 1972[37]

(Thousand Cubic Feet)

Preservative	Poles	Railroad Ties	Lumber and Timbers	Fence Posts	Piling	Switch Ties	Cross-arms	Other	Total
Creosote and Creosote-Coal Tar	26,054	60,610	11,869	6,591	13,362	4,702	373	1,890	125,453
Creosote-Petroleum	376	25,070	1,020	752	200	1,215	-	254	28,887
Petroleum-Pentachlorophenol	45,230	79	16,394	9,924	239	50	2,093	1,786	75,795
Chromated Copper Arsenate	1,497	75	22,187	753	486	-	-	618	25,633
Fluor Chrome Arsenate Phenol	-	45	4,440	27	19	-	0	938	5,475
Creosote-Pentachlorophenol	1,128	0	83	0	0	0	0	0	1,211
Chromated Zinc Chloride	-	0	918	0	0	0	0	0	918
Acid Copper Chromate	0	0	1,913	0	0	0	0	0	1,913
Fire Retardants	0	-	4,250	-	0	0	0	1,560	5,815
All Others	-	-	858	-	17	0	-	186	1,433
Totals	74,537	85,880	63,950	18,175	14,324	5,971	2,487	7,227	272,551

Note: Components may not add to totals due to rounding.

TABLE XI

WOOD PRESERVATIVES USED (1972)

Preservative	Amount Used in 1972 (millions of pounds)	Change Since 1968 (%)
Organic Preservatives[a]		
Creosote	970.0	-11
Pentachlorophenol	38.0	+14
Inorganic Preservatives[37]		
Chromated Copper Arsenate	9.8	+230
Fluor Chrome Arsenate Phenol	1.9	-42
Acid Copper Chromate	1.2	+12
Chromated Zinc Chloride	0.6	-11
All Others*	1.0	-5
Total Inorganic Preservatives	14.5	

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[a] MRI estimates.

* According to a Koppers Company spokesman use of ammoniacal copper arsenite is as great as that of acid copper chromate and more than that of chromated zinc chloride.

essentially constant. These trends are expected to continue, except that an increase in the production of fire-retardant treated wood is anticipated.

The wood preserving industry is composed of more than 400 small, privately-owned companies with long-standing technology and largely depreciated plant and equipment. The top four producers account for about 35% of production and are owned by large, public corporations that are primarily in the chemical and timber products business. The industry is located primarily in the South and Northwest. A map showing the location of wood treatment plants in the United States is presented in the section of this report describing creosote (Case Study No. 20) in Chapter X.

A brief description of the various processes used to treat wood is also presented in the case study for creosote. Also discussed in the same section are some of the waste treatment problems that are encountered in the preservation of wood.

Effluent limitation guidelines are presently being drafted for this industry by the EPA. Dr. Warren S. Thompson of Mississippi State University is directing this work. An economic analysis of the proposed effluent guidelines is being performed by Arthur D. Little, Incorporated.

2. Railroads: Railroads are concerned with controlling vegetation along their rights-of-way. Vegetation control is mandatory on an 8 to 24-ft wide band centered over the rails. This control zone constitutes a firebreak to protect adjacent properties from sparks thrown off by the wheels of railroad cars. The faster the trains travel through an area, the wider is the required weed-free area. In addition, weeds shorten the life of railroad ties, can reduce traction for braking, reduce drainage, and foul the ballast on tracks.

There are approximately 330,000 miles of track in the United States. Three distinct areas on the track require weed control: the ballast, the roadbed, and the right-of-way. The ballast is a strip 12 to 16 ft wide, made of coarse material such as cinders or gravel, and is very porous. Insoluble and contact herbicides are the most suitable for use on the ballast. The roadbed and rights-of-way require soil sterilants to remove vegetation and provide the firebreak mentioned above.

Many herbicide mixtures are used. The most common ones include chlorate-borate mixtures, bromacil, MSMA, and 2,4-D. Some herbicides are water soluble and leach well into the soil to control deep-rooted weeds. Examples of water soluble herbicides are bromacil, chlorate-borate, TCA, and dalapon. Other herbicides such as atrazine, diuron, and prometone are not water soluble, and are suitable for use on the ballast. Often the railroads use a combination of a soil-active, contact foliar, and selective herbicide, because application costs are high and they want to get as complete sterilization as possible from each application. Fairly typical combinations would be: chlorate-borate, MSMA and 2,4-D; and bromacil, MSMA and 2,4-D.

Total acreage treated by the railroads with herbicides amounts to about 1.6 million acres, which includes the tracks, the yards, and the bridges and sidings. An estimated 20 million pounds of chemicals are used annually for this purpose by railroads in the U.S.* The chlorate-borate mixtures account for the majority of chemicals with an annual application of about 12.6 million pounds. Other chemicals used in excess of 1 million pounds are 2,4-D, MSMA and bromacil. Table XII lists the herbicides used by railroads.

Application of the herbicides is generally done by application companies, although some railroads, notably the Santa Fe and Union Pacific, treat most of their own tracks. Application companies use High-rail equipment that can run on rails with one set of wheels and on roads as a truck. They can be operated by one man and do not require the use of a train crew. Some of the leading application companies are:

R. H. Bogle	Alexandria, Virginia
Nalco	Chicago, Illinois
Habco	Minneapolis, Minnesota
Namco	Milpitas, California
Mobley	Kilgore, Texas

In addition to herbicides, railroads are major users of creosote, as discussed in Section 1.

3. Utilities: The utility companies are concerned with controlling vegetation along their rights-of-way. Utility rights-of-way include land areas devoted to the transmission of communications, electrical power, gas, and fluids such as oil, sewage, and water. Transmitting devices may be underground, laid on the soil, or suspended overhead on poles and towers. The land area involved is long and narrow--usually many miles long by 10 to 200 ft wide.

The rights-of-way may be located in isolated rural areas having widely varying terrain, in heavily populated rural areas, or in urban areas. Initial clearance of vegetation and woody plants is usually done by mechanical means. Normally, trees are cut and burned; low lying vegetation

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* Data in this section were estimated by Dr. Dale W. Young.

TABLE XII

ESTIMATED HERBICIDE USE BY RAILROADS[a]

Compound	Rate/Acre (lb)	Acres Treated (thousands)	Total Pounds (thousands)
Chlorate-borate	110	115	12,650
2,4-D	4	400	1,600
MSMA	4	330	1,320
Bromacil	4	300	1,200
TCA	100	7	700
Diuron	10	70	700
2,4-D + 2,4,5-T	4	110	440
Atrazine	10	40	400
Prometone	10	30	300
Krovar	6	40	240
Amino triazole	2	110	220
Dalapon	6	30	180
2,4,5-T	10	10	100
Tandex	4	10	40
	TOTAL	1,602	20,090

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[a] Source: Dr. Dale W. Young.

is cut with tractor-drawn mowers, disced, chopped or root-plowed, and then seeded to grasses and legumes.

After installing the transmission lines, the most common means of controlling vegetation is by the use of herbicides. In the case of suspended utility lines, a critical control requirement is preventing trees from growing into or falling onto the lines. All utility rights-of-way must be kept clear and the lines made readily accessible to work crews since inspection, maintenance, renovation, and repair must be performed without interference. The types of herbicides used vary widely, depending on the site and the plant species being controlled.

The most common herbicides used by the utilities are 2,4-D, 2,4,5-T, Ammate®, silvex, and Tordon®. Total herbicide usage by the industry is about 5 million pounds annually with 2,4,-D and 2,4,5-T accounting for 70% of the chemicals used.* Ammate is used primarily when danger of drift to agricultural crops is important. Table XIII lists the herbicides used by utilities.

Application is generally made by contractors. Some of the larger ones are:

Asplundh Tree Experts	Jenkintown, Pennsylvania
Bartlett Tree Experts	Stamford, Connecticut
Davey Tree Experts	Kent, Ohio
Campbell Air Service	Vivian, Louisiana

To achieve maximum efficiency with herbicides, the control program used on a given site should take several factors into account: (1) the locations of woody-plant problems; (2) the dominate species and relative percentages of these species; (3) the densities of woody plant stands; (4) the heights of woody plants; (5) accessability of areas to be treated; (6) potential effects of treatment on vegetation and adjacent crops, fish, and wildlife; (7) potential hazards to applicators; (8) prior treatments with herbicides and results obtained; and (9) the objectives desired in vegetation control. Applications of the herbicides used include foliar treatment, basal-bark treatment, dormant-stem treatment, frill treatment, injection technique, basal-soil treatment and pellets.

Approximately 1/3 of all applications in the utilities' industry are accomplished by aerial spraying, mostly by helicopter. Ground applications are commonly performed using four-wheel-drive vehicles equipped with 300 to 400 gallon spray tanks, 20 gpm sprayers, and reels of 1/2-inch

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* Data in this section were estimated by Dr. Dale W. Young.

TABLE XIII

ESTIMATED HERBICIDE USE BY UTILITIES[a]

Compound	Rate/Acre (lb)	Acres Treated (thousands)	Total Pounds (thousands)
2,4,5-T	6	280	1,680
2,4-D + 2,4,5-T	4	380	1,520
Ammate	100	5	500
Silvex	8	60	480
2,4-D	4	100	400
Tordon	5	80	400
	TOTAL	905	4,980

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a/ Source: Dr. Dale W. Young.

diameter oil-resistant hose and spray guns. On accessible rights-of-way, a cluster of jet nozzles mounted on a four-wheel-drive vehicle are used to apply low volume sprays to 50-ft swathes of land; the effect is similar to that obtained by spraying from a helicopter.

In addition to the herbicide usage, creosote and pentachlorophenol are used to treat utility poles to protect them from destructive pests. This use was previously discussed in Section 1.

4. Stored grains and feeds: The amount of grain stored commercially in the United States fluctuates widely. For example, in recent years, 300 million bushels of wheat have been stored annually, but in 1973 practically no wheat was stored because of the exceptionally large sales to Russia. It is estimated that of all the grain stored in the United States, 65% is fumigated, 20% is treated with malathion, and the remaining 15% (which represents mostly short-term stored grain) is not treated at all.

Of the grain that is fumigated, about 40% is fumigated with phosphine, 40% with liquid fumigants, and 20% with methyl bromide. The total use of phosphine is about 97,000 lb (phostoxin, AlP) at the present time, but is growing at a rate of 25% per year. One pound of aluminum phosphide will fumigate over 500 tons (17,000 bu) of grain. The liquid fumigants are based mostly on carbon disulfide, chloroform, and carbon tetrachloride. Methyl bromide, the most widely used bromide fumigant, is used undiluted. Methoxychlor has some use in treating bins before the grain is added.

The malathion is an emulsifiable spray and the grain is treated prior to binning. The residual tolerance for malathion is 8 ppm, but the tolerance may be lowered; this action might stimulate the use of pyrethrin, which is small at present. All of the grain going to Russia was treated with malathion; a 57% concentrate was applied as 1 pt in 5 gal. of water per 1,000 bu of grain.

Grains are treated when placed in the bin except for soy beans, which do not become infested. The malathion or pyrethrum treatment can give 1-2 year protection, depending on the tightness of storage, humidity, etc., but treatments are usually conducted more than once a year, especially when insects are found. In general, stored grains are fumigated twice yearly in the northern part (sometimes a third time) and three or four times yearly in the southern part of the United States.

5. Food and beverage industry: The food and beverage industry uses large amounts of fumigants to control insect pests. Raw materials in storage are fumigated as well as foods which become infested with insects. Methyl bromide and phosphine (applied as aluminum phosphide) are the most common fumigants used with foods. If the product or processing equipment

absorbs methyl bromide (such as fat-containing or iodine-containing products), then phosphine is used. Another space fumigant used in milling, baking, and food-processing machinery is a mixture of 34% acrylonitrile and 66% carbon tetrachloride (by volume).

Pesticides are used extensively to control insects infesting the plant sites in the food and beverage industry. The biggest hazard involved with the use of chemical pesticides is contamination of the food products. Therefore, dursban diazinon, and pyrethrins are commonly used because of their relatively low toxicity. Pyrethrin is used extensively by bakers, dairies, and brewers. Korlan (Ronnel) is widely used by dairies because there are fewer restrictions on its label. Baygon and Entex (fenthion) are used in limited quantities. Brewers, particularly, must guard against wild yeast growth in their equipment and lines; a fluorosilicate is often used for this purpose.

The company may either do its own pesticide work, or contract it to pest control operators (PCO). Bakers and bottlers do most of their own work. Butchers, brewers, and dairies may do their own work or contract it.

6. Professional pesticide application services:

a. Pest control operators: Pest control operators (PCO's) are commercial firms that provide service for institutional, commercial, industrial, and residential clients. Both insect and vertebrate pests are controlled by PCO's using a wide variety of chemicals. (In this report, PCO's are distinguished from lawn and tree service organizations, although there is overlap between these organizations). Most of their work is done indoors and is divided into two major categories--structural PCO's (exterminating, wood-destroying organisms) and general PCO's. Approximately 11,000 individual firms exist throughout the U.S. but about half of them are one- or two-man operations. The two largest companies are Orkin and Terminex, each having numerous firms located across the country. The total dollar volume of the PCO industry in 1973 is estimated at $600 million of which $30 million is represented by the cost of the pesticides employed.

Little quantitative information is available conerning the usage of chemicals by these firms and the clients that they serve. About 30% of the PCO's in the U.S. are members of the National Pest Control Association in Washington, D.C. Dr. C. D. Mampe, Director of Technical Services for NPCA, furnished the report of a survey they had conducted. Entitled "Relative Importance of Insecticides Used Indoors", this survey determined the relative usages of different pesticides by PCOs in the past 9 years. The survey results, presented in Table XIV, shows that Dursban, diazinon and DDVP (dichlorvos) are the most frequently used insecticides.

TABLE XIV

RELATIVE IMPORTANCE* OF INSECTICIDES USED INDOORS 38/

by PCO's from Survey of NPCA
Insect Control Committees

INSECTICIDE	1973	1972	1971	1970	1969	1968	1967	1966	1965
No. of PCO's in Survey	42	46	38	41	43	37	37	36	33
Dursban	2.57	2.46	1.83	1.83	1.21	-	-	-	-
Diazinon Spray	2.42	2.48	2.42	2.29	2.79	2.70	2.81	2.86	2.30
DDVP Spray Additive	2.14	1.85	1.95	1.76	1.84	1.78	1.57	1.81	1.55
Chlordane Spray	1.88	1.48	1.84	1.88	1.74	2.19	2.11	2.06	2.24
Pyrethrins Sprays + Synergist	1.83	1.54	1.34	1.24	1.40	1.32	1.14	1.56	-
Baygon Bait	1.59	1.46	1.60	1.51	1.16	1.16	-	-	-
Pyrethrins + Synergist as Spray Additive	1.50	1.35	1.16	1.41	1.18	1.41	1.22	1.39	-
Chlordane Dust	1.35	0.93	0.95	1.22	0.81	1.11	0.94	1.00	1.33
Baygon Spray	1.33	1.61	1.60	1.44	1.30	1.24	1.54	1.53	1.52
Kepone Pellets	1.33	1.07	1.03	1.15	1.19	1.46	1.70	0.83	1.18
Pyrethrins Spray	1.23	1.37	0.79	1.02	0.74	0.48	0.73	0.67	-
DDVP Spray	1.21	0.89	0.97	1.00	0.86	1.14	1.00	1.39	1.55
Pyrethrins Dust	1.19	1.06	1.18	0.76	0.88	0.68	0.54	1.14	-
Malathion Spray	1.14	1.09	1.13	1.15	1.09	1.03	1.05	1.19	1.15
Pyrethrins Dust + Synergist	1.07	0.80	0.74	1.07	0.91	0.84	0.57	0.61	-
Diazinon Dust	1.00	1.26	0.84	0.83	0.95	0.84	0.73	0.89	0.67
Kepone Paste	0.97	0.83	0.63	0.88	0.91	1.08	0.81	1.06	0.91
Paradichlorobenzene	0.97	0.65	0.60	0.76	0.51	0.76	0.78	0.56	0.85
Sevin Dust	0.95	1.04	1.16	0.85	1.05	0.76	0.49	0.64	0.58
DDVP Resin Strips	0.90	0.98	0.74	1.02	0.86	1.03	1.00	1.06	-
Pyrethrins Spray Additive	0.88	0.87	0.63	0.93	0.77	0.59	0.68	0.56	-
Silica Gel	0.83	0.76	0.42	0.59	0.60	0.68	0.65	1.22	0.48
Sodium Fluoride	0.78	1.02	0.79	0.76	0.86	0.97	0.97	1.22	1.24
SEP-1382	0.73								
Phosphorus Paste	0.69	0.41	0.55	1.17	1.05	1.14	1.14	1.22	1.03
Dipterex Bait	0.54	0.28	0.29	0.22	0.23	0.22	0.16	-	-
Malathion Dust	0.45	0.37	0.47	0.34	0.30	0.41	0.27	0.28	0.70
Korlan (Ronnel)	0.40	0.33	0.26	0.22	0.42	0.54	0.22	0.36	0.24
Repellents	0.40	0.52	0.42	0.73	0.40	0.35	0.35	0.36	0.55
Naphthalene	0.38	0.17	0.13	0.29	0.19	0.24	0.30	0.36	0.36
Lethane	0.21	0.11	0.03	0.24	0.19	0.24	0.24	0.44	0.45
Dibrom	0.14	0.06	0.16	0.22	0.21	0.19	0.08	0.31	0.21
Baits	1.85	1.81	1.74	1.94	1.77	1.92	1.54	1.81	-
Dusts	1.83	1.98	1.97	2.00	1.84	2.08	1.68	1.94	-
Water Base Spray	2.38	2.74	2.58	2.83	2.49	2.62	2.08	2.67	-
Oil Base Spray	1.52	1.81	1.63	1.60	1.42	2.14	1.57	1.94	-

*Index Number = $\frac{\text{(Seldom used) + 2 (Frequently used) + 3 (Regularly used)}}{\text{Number of questionnaires returned}}$.

In regard to the clients served, a survey conducted by Avitrol corporation at the NPCA convention in St. Louis, Missouri in 1972, revealed that the types of accounts the PCOs handle break down into 46.3% for residential work; 45.7% for commercial work; and less than 8% for agricultural work. The survey also revealed that nearly 70% of the PCOs questioned were involved in bird control work. The top three pest birds were pigeons, sparrows, and starlings, with blackbirds, gulls, and crows next in order of importance. Airports, railroad yards, bridges, and feedlots are areas that frequently require bird control.

A wide variety of insects and vertebrates are encountered in the institutional, commercial, and industrial sector served by PCOs. About 1/4 of their business in this area involves rodents, with most of the remaining work involving the control of insects. The most important and prevalent insects are roaches, termites, and ants.

The best information available on rodent control by PCOs has been presented by C. D. Mampe.[39] He presents the following facts:

Rodents controlled: A 1967 NPCA survey found that rodent control involved Norway rats (43%); house mice (39%); tree squirrels (5%); roof rats; and various other vertebrate pests of lesser importance such as ground squirrels, moles, and pocket gophers.

Rodenticides used: In 1970, anticoagulants accounted for 95% of all chemicals used as rodenticides. Second was DDT tracking powder and third was zinc phosphide. Strychnine, thallium sulfate, sodium fluoroacetate (1080), and phosphorus were used infrequently.

1970 market: About 27,000 servicemen were in the industry in 1970. Twelve million pounds of bait were used (600,000 lb of concentrate) by PCOs, accounting for 70% of the U.S. anticoagulant market. Concentrates are marketed as 0.5% with the exception of Diphacinone, which is marketed as a 0.1% concentrate. Baits contain 5% concentrate, i.e. about 0.025% AI.

In the U.S. commensal rodents account for most of the problem. Norway rats, house mice, and roof rats are the predominant commensal rodents. Norway rats and house mice occur in the interior and northern parts of the country, while the roof rat is established in the Southeast, Texas, southern California and the coastal regions.

Industrial losses are of three general types: consumption of foodstuff, contamination of foodstuff, and gnawing damage to miscellaneous objects. Rodents are a problem in nearly all phases of food processing, especially milling and storing cereal grains and products. General warehouses and the shipping industry also must deal with rats constantly. Although many food processors, warehousers, shipppers, and food handling firms do their own work, PCOs serve many clients in this industrial-commercial area. (A break-down between commercial and residential rodent control is unavailable).

Insect control work involves primarily structural control of pests which either damage or infest the structure. Termites, carpenter ants, and powder post beetles are the predominate wood-destroying insects encountered by structural pest control operators. Roaches, ants, spiders, silverfish, beetles, and houseflies are types of infesting insects commonly encountered by general pest control operators.

The wood-destroying insects are primarily controlled by the use of chlordane and aldrin (about 70% and 30% use, respectively) with minor amounts of heptachlor and dieldrin also employed. Infesting insects can be controlled by a variety of insecticides. The chemicals of choice depend primarily on the "structural PCO" doing the work and his control procedures. Some common insects are listed below with insecticides that can be used to destroy them.

Roaches - Malathion, Diazinon, Ronnel, Dieldrin, Trichlorofon, Baygon, Fenthion, Chlordane, Pyrethrum, Dichlorvos, Lindane, Kepone;

Ants - Chlordane, Dieldrin, Heptachlor, Aldrin;

Silverfish - Lindane, Chlordane, Malathion, Diazinon, Pyrethrum;

Beetles - Diazinon, Chlordane, Malathion, Lindane, Dieldrin, Methoxychlor;

Houseflies - Diazinon, Ronnel, Malathion, Dimethoate (outdoors);

Crickets - Pyrethrum, Chlordane, Lindane, Malathion, Diazinon.

The only other quantitative data for PCOs located during our study came from the state of Kansas. Their annual report "Activities of the Division of Entomology, Kansas State Board of Agriculture, Topeka, Kansas, 1972"[40/] summarizes the use of individual pesticides by PCOs in 1972. These data are given in Table XV. Chlordane is seen to be the most popular, by far.

TABLE XV

ESTIMATED INSECTICIDE USE BY PCO'S AND TREE SPRAYERS IN KANSAS, 1972[40]

	Tree Sprayers	General Pest Control Operators	Pest Control Operators Structural	Total
Chlordane	573	14,716	210,216	225,505
Aldrin		83	67,377	67,460
Dieldrin	48	656	20,623	21,327
Malathion	2,764	18,497		21,261
Carbaryl	20,371	42		20,413
Diazinon	791	11,597		12,388
Lead Arsenate	7,410			7,410
Methoxychlor	5,282			5,282
Fenthion	182	3,330		3,512
Dichlorvos		1,425		1,425
Chlorpyrifos	18	1,266		1,284
Toxaphene	1,255			1,255
Heptachlor			870	870
Baygon®		593		593
Dicofol	500			500
Azinphosmethyl	318			318
Chlorobenzilate	91	17		108
Tetradifon	79			79
Akton®	9	33		42
Benomyl	36			36
Pyrethrums		19		19
Dimethoate	9			9
Kepone®		2		2

The types of institutional, commercial, and industrial establishments employing PCOs are not available statistically, and are obviously too numerous to list here. These establishments may either contract PCOs or perform the work themselves. If they do it themselves, the chemicals used are purchased primarily from janitorial supply houses and chemical firms.

b. Lawn and tree services: Pest control firms that take care of lawns and trees are a separate group from PCOs (although many firms providing diverse services would fall under both categories). There are an estimated 15,000 individual firms providing lawn and tree care in the U.S.

No statistical data is availabel to indicate how much of their work is residential and how much is in the commerical-industrial-instituttional sector. Their work primarily involves pest control in grass, trees, and shrubs. Therefore, they differ from PCOs--particularly structural PCOs--primarily in that they use large amounts of herbicides. However, they also use insecticides to control lawn, tree, and shrub pests.

Lawn problems they encounter most often and the pesticides employed are: (1) crab grass (dacthal and chlordane); (2) broad-leaf weeds (2,4-D); and (3) sod webworms (diazinon, Dursban, and Sevin). Pests commonly encountered in trees and shrubs are bagworms, beetles, mites, scale insects, and aphids. Insecticides used to control these pests vary widely, but most are the carbamate and organophosphorus compounds.

Amounts of insecticides used in the State of Kansas by licensed tree sprayers was presented in Table XV.

c. Other professional applicators: In addition to the pest control operators and lawn and tree services, custom applicators servicing primarily agriculture also exist. Though custom applicators do not normally do industrial or commercial work, they are included in this section because they fall under the professional pesticide application services category. Both ground and aerial applications are made to crops and orchards. Table XVI lists the total pounds of technical product used in 1972 by custom applicators in the State of Kansas.*

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* The large amount of disyston reflects a wheat problem and is not representative nationwide.

TABLE XVI

ESTIMATED QUANTITIES OF INSECTICIDES USED BY CUSTOM APPLICATORS IN KANSAS IN 1972[40]

Insecticide	Pounds Technical Used in 1972	Insecticide	Pounds Technical Used in 1972
Di-Syston	229,158	Diazinon	13,842
Carbaryl	161,889	Bux	10,272
Parathion	128,345	Malathion	8,642
Dimethoate	95,520	Methoxychlor	2,647
Toxaphene	92,629	Dasanit	2,041
Thimet	62,095	Heptachlor	1,224
Furadan	48,752	Trithion	861
Ethion	26,186	Systox	359
Aldrin	18,128	Endrin	319

Some of the firms engaged in pest control work specialize in one industry, such as railroads, or utilities, and some specialize in the type of work they do, for example, ditching and irrigation contractors.

7. Janitorial supply services: Those firms which do not contract pest control work, purchase many of the chemicals that they use from janitorial supply houses. There are approximately 5,500 of these janitorial supply houses in the U.S. and they handle large volumes of pesticides. The total dollar volume is estimated to be greater than that for the PCOs, but the amounts of active ingredients are probably less since they handle primarily ready-to-use pesticides (i.e., already formulated). In addition to selling pesticides they sell disinfectants, sanitizing agents, cleaning agents, etc., normally associated with janitorial work. Some of them are beginning to offer pest control services on a limited scale, and this aspect of their business is expanding.

Institutions and commercial firms such as restaurants and grocery stores buy from janitorial supply houses. Pyrethrin and Diazinon (1/2%), used as roach sprays, are the primary pesticides handled, but malathion and others are also sold. Fly baits, rat and mouse baits, and residual insecticides, such as Korlan, are also handled.

8. Textiles: Cotton textiles consume a greater quantity of industrial fungicides than any other product, with the exception of the wood products. Tennis nets, fishing lines, sails, tobacco shade cloth, tarpaulins, awnings, and tents must be protected because they are continuously exposed to the weather. However, industrial filter cloths, shoe linings, diapers, and umbrellas are also subject to biological deterioration. In 1970, 3.815 billion pounds of cotton were consumed in the United States and an estimated 400 million pounds of this total was made into the above products. An average (see below) of about 1% of the cotton's weight is fungicide for preservation. Thus about 4 million pounds of fungicides are used for this purpose in the United States. The most important fungicides for this use are the copper fungicides, with copper naphthenate having been used to treat a greater quantity of cellulosic textiles than any other chemical or mixture.

The three most important compounds used in the protection of textiles and cordage, and representing the major portion of fungicides used in industry for this purpose are: 1) copper naphthenate, 2) copper 8-quinolinolate, and 3) dichlorophene. The concentrations of each fungicide normally put in the fabric as a percent of the fabric's weight are, respectively: 1) 0.3-1.0%, 2) 0.15-2.0%, and 3) 0.5-2.0%. These compounds are typically used to preserve commercial fishing nets, sand bag material, camouflage, netting, cotton duck, and cordage from cotton, hemp, and manila. Copper naphthenate is never used with fabrics which contact rubber because it catalyzes the oxidation of rubber. In these cases, zinc naphthenate is commonly used.

Institutional laundries formerly used phenylmercuric acetate and phenylmercuric propionate as fabric treatment in the final rinse cycle to prevent mold growth in the storage and shipping of soiled linens, diapers, and hospital clothing. Salicylanilide (Shirlan®) is used for stored fabrics and can be washed out at the end of the storage period.

Other compounds used as textile or cordage preservatives include copper oleate, copper tallate, copper resinate, hydroxy copper naphthenate, copper 3-phenylsalicylate, cuprammonium carbonate, cuprammonium hydroxide, cuprammonium fluoride, zinc dimethyldithiocarbamate, 2-mercaptobenzothiazole, phenylmercuric acetate, phenylmercuric oleate, phenylmercuric triethanolammonium lactate, tributyltin oxide, and various phenol derivatives.

9. Paint: Paints are composed of polymers and other ingredients, and are applied as a film to a surface on site. The two main functions of paint are appearance and protection. Fungicides are often added to paints to prevent molding, mildew and fungus attack. Paints are formulated in different ways depending on their intended use; some classifications include exterior building paints, interior latex paints, and marine paints.

At one time it was thought that mildewing of paint surfaces was typical only in the warm, humid regions of the South, but examination of painted surfaces around the country and in Canada showed that this was not true; what was often thought to be dirt was actually mold. Many species of fungi are found on paint films, but the most prevalent one by far is P. pullulans. Aspergillus and Penicillium are found on indoor surfaces in high humidity areas, such as in textile mills, locker rooms, and breweries. Flavobacterium marinum is the most common bacteria found on deteriorating paint films at the interface between the wood and paint, and this growth is suggested as the cause of deterioration of paint films by peeling.

The most widely used paint preservatives are phenylmercuric salts of various organic acids. The three more common compounds and types of paints they are used in are phenylmercuric acetate (latex water-base), phenylmercuric oleate (oil base), and phenylmercuric propionate (oil and water base). These compounds are typicallly applied in the paint at a concentration of 0.01-1.5% by weight. Two recently developed mercury fungicides that may be used in paint are chloromethoxypropyl mercuric acetate and o-hydroxymercuribenzoic acid, cyclic anhydride. In addition to the mercurial compounds, copper compounds, calcium carbonate, and barium metaborate are added to paints to inhibit mold.

Latex exterior paints use the above compounds at a typical concentration of 1% to prevent mildew and mold. Interior paints do not use mercury since it is toxic, and commonly use salicylanilide or organotin compounds (tributyltin hydroxide and tributyltin acetate) because of their low toxicities. These compounds are less effective than the mercurials, and the concentrations used in paints are often as high as 10%.

Marine paints are used to protect ships and boats. Regular paints can be used to protect the ship in all areas except the bottom and boot-topping, where the marine paints are used. The bottom is the portion of the hull that is always under water, and subject to marine vegetable and animal organisms. The boot-topping area is the portion of the hull that is intermittently immersed and exposed to air, commonly known as the "wind and water line". This area receives extreme exposure to the elements.

Marine paints use antifouling mercury and copper compounds, and organotin compounds. The tributyltin formulation have been found to protect wood and metal boats against harmful marine organisms, and do not corrode aluminum or steel. Tributyltin fluoride, bis(tributyltin) oxide, and bis(tributyltin) sulfide are commonly used.

10. Water management: The industrial, commercial and institutional uses of water generates many needs for water management: weeds, insects, and fungus growths require control by herbicides, insecticides, and fungicides. Weeds are troublesome in static water areas such as: marinas; fish hatcheries; landscaping, recreational and settling ponds or lakes; reservoirs and earth tanks; and in flowing water areas such as ditch banks. Insects, particularly mosquitoes, create problems in static water areas.

Control of algae and fungi is important in industrial processing waters and in cooling towers. Algicides and fungicides are added to the water to inhibit algal and fungal growth. Sodium pentachlorophenate, used at an annual rate of 3 million pounds, is the most widely used compound. The organotins also serve this purpose well; bis(tributyltin) oxide is a common choice. The wood used in construction of cooling towers may also be treated with the chromated preservatives, e.g. the CCA salts.

Weeds are by far the biggest problem, and can be divided into three major groups: 1) floating, 2) submersed, and 3) emersed. Chemical control of each group of weeds varies with the species involved.

Floating weeds germinate in the bottom of a ditch or standing body of water, then become separated and float. Common weeds in this group are duckweed, water lettuce, water fern, water hyacinth, floating alligator weed, and anchored floating-leaf weeds such as water lily and water shield. These weeds and the herbicides commonly used to control them are listed below.

Weed	Herbicide	Application Rate (lb A.I./acre)
Duckweed	Diquat	0.5 to 1.0
	2,4-D	2 to 4
Water lettuce, Water fern	Diquat	1 to 1.5
	2,4-D	2 to 4
	Amitrole-T*	2 to 5
Water hyacinth	2,4-D	2 to 4
Alligator weed	Silvex	4 to 8
	2,4-D	4 to 8
Water lily, Water shield	2,4-D	2 to 4

Submersed weeds are those which are entirely under water. Common species include pondweed, naiad, water milfoil, water crowfoot, waterweed, water star grass, and the nonrooted species such as algae. Control techniques vary depending on whether the water is static or flowing. Consideration must be given to the toxicity of some of the herbicides used. In ditches and streams where the water is flowing at 0.25 ft or more per second, only aromatic solvents (methylated or chlorinated benzenes such as xylene and trichlorobenzene) and acrolein provide satisfactory control. Both aromatic solvents and acrolein are deadly to fish. In reservoirs carrying water for industrial uses, copper sulfate is used at 0.6 to 1.0 ppm concentration to control algae and rooted submersed weeds. In static water, such as ponds and lakes, several chemicals are applied. The herbicides commonly applied to control submersed rooted weeds are listed below:

Herbicide	Application Rate
Sodium arsenite	2-10 ppm
2,4-D	20-40 lb/acre
Silvex	2-4 ppm
Endothall	2-5 ppm
Dichlone	2-11 ppm
Dichlobenil	7-10 lb/acre
Fenac	15-20 lb/acre
Diquat	3-4 ppm

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* Now banned in the U.S.

Algae is controlled by copper sulfate (0.5-1.0 ppm); dichlone (0.2-0.5 ppm), roccal (0.5 ppm), diquat (0.5-0.7 ppm), sodium arsenite (2-8 ppm), and simazine (10 lb/acre). Copper sulfate is the safest, most effective, inexpensive, and extensively used algicide.

Emersed and marginal weeds are rooted below the surface, but rise above the waterline. Common species include alligator weed, arrowhead, bulrushes, burweed, cattails, emergent parrot feather, grasses, lotus, pickerelweed, primrose willow, reeds, rushes, sedges, smartweeds, spatterdock, spikerushes, swamp loosestrife, water chesnut, watercress, water lilies, water primrose, and water shield. The aquatic grasses, sedges, cattail, and bulrushes are controlled by Amitrole-T (now banned) at 4 to 16 lb/acre, 2,4-D at 4 to 8 lb/acre, or dalapon at 10 to 30 lb/acre. Most of the other weeds are controlled by 2,4-D or Silvex at 2 to 8 lb/acre. Silvex is more effective than 2,4-D on alligator weed and spatterdock.

The quantities of the herbicides most widely used in water management are estimated as shown in Table XVII (note that these data would include management on government-owned waters).

Insects, especially mosquitoes, are a problem around water. Mosquito control takes two principle forms: 1) chemical control of the larvae, and 2) space spraying with mist blowers or thermal fog generators to control adult mosquitoes. Larvicides commonly used are (1) No. 2 fuel oil (15-25 gal/acre); (2) pyrethrum larvicides, such as a mixture of pyrethrins, oil, and an emulsifier known as New Jersey larvicide; and (3) various chlorinated hydrocarbons and organophosphates. A list of the latter group follows:

Chemical	Application Rate (lb A.I./acre)
Abate	0.05
DDT	0.2
BHC	0.2
Chlordane	0.1
Heptachlor and Dieldrin	0.1
Malathion	0.25-0.5

Adult mosquito control around water consists of spraying or fogging when the adults are present. Various insecticides have given good control when used in mists or fogs. Some of them are listed below with their rates of application.

TABLE XVII

ESTIMATED TOTAL WATER MANAGEMENT HERBICIDE USE[a]

Chemical	Rate/Acre (lb)	Acres Treated (000)	Total Herbicide (million lb)
2,4-D	3	400	1.20
Dalapon	20	30	0.60
Ammate	100	5	0.50
MSMA	4	80	0.32
Aminotriazole	10	25	0.25
Silvex	4	60	0.24
Diuron	10	9	0.09
2,4-D + 2,4,5-T	4	20	0.08
Atrazine	10	5	0.05
Bromacil	5	8	0.04
Paraquat	0.5	40	0.02
	TOTAL	682	3.39

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[a] Source: Estimates by Dr. Dale W. Young.

Chemical	Application Rate (lb A.I./acre, except as indicated)
5% DDT	0.3 to 0.5
2.5% Chlordane	0.1 to 0.2
2% Lindane	0.1 to 0.2
3% Malathion	25 gal/linear mile
Naled	0.02

11. Commercial forests: Privately-owned forest land in the United States totaled 545 million acres in 1964. Forestry statistics by state show that only part of this land is under forest management, but the amount being managed today has grown and continues to grow. Table XVIII gives the data compiled in 1964*.

Forest management primarily involves providing favorable growing conditions for desired species and controlling the forest-species composition. Measures to achieve the desired results include: thinning stands of desired species; reducing shrub and unwanted small tree growth to prepare for forest regeneration; treating to release seedlings or saplings of desired species from other competing species; and killing cull trees and trees of unwanted species in older stands. Many tracts of managed forest will not need such measures, and mechanical means may be used rather than herbicidal. However, every forest under management is a potential site for application of weed-control measures at some time during the life of the stand, and herbicides are usually the most effective and convenient means of control.

Herbicide control techniques vary depending on the state of the forest at the time of application. The forest may be established , may be in the process of establishment, or may be going through a process of site preparation prior to planting.

Site preparation usuallly involves one or more of the following objectives: (1) removing brush, (2) removing physical obstacles, and (3) preparing the ground for seeding. Mechanical means have an advantage over herbicides in that the ground can be prepared while removing brush, whereas herbicides leave dead vegetation that must normally be removed either mechanicallly or by burning prior to seeding. Herbicides are used, however, and the most effective and widely used chemicals are low-volume esters of 2,4-D and 2,4,5-T. Other chemicals used include silvex, Amitrole,

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* Source: State Forestry Statistics 1964, "Forests and Forestry in the American States", National Association of State Foresters,(1968).

TABLE XVIII

FORESTRY STATISTICS BY STATE, 1964[41]

State	Area (in Acres) of Privately Owned Forest in State	Area (in Acres) of Privately Owned Forest Lands Over 100 Acres	% of Forested Area in Private Ownership	% of Privately Owned Forested Area Under Forest Management
Alabama	21,742,200	15,236,800	95	50
Alaska	40,000,000	1,240,000	1.7	None
Arizona	3,200,000	112,500	4	50
Arkansas	20,757,000	13,056,000	86.2	28
California	17,391,000	7,670,000	46.3	76
Colorado	12,275,000	1,457	36	3
Connecticut	1,973,000	832,000	92	20
Delaware	391,000	-	-	-
Florida	19,600,000	17,100,000	82.5	30
Georgia	25,772,000	19,844,979	93	34
Hawaii	1,088,900	Not Avail.	54	2
Idaho	15,823,000	2,869,360	14	60
Indiana	4,082,000	543,003	93	15
Iowa	2,595,000	129,000	98	45
Kansas	1,664,000	190,000	100	Unknown
Kentucky	11,446,000	5,472,000		
Louisiana	16,038,000	9,046,000	94.7	50
Maine	17,169,000	12,832,000	98.8	45
Maryland	2,563,216	1,584,000	90	22
Massachusetts	3,200,000	1,600,000	88	10
Michigan	19,120,700	7,161,000	67	20
Minnesota	17,062,000	-	44	20
Mississippi	17,193,600	10,900,000	90	Not Avail.
Missouri	14,996,300	7,910,000	89.3	15
Montana	15,727,000	4,562,000	30.9	70
Nebraska	1,050,400	22,000	91	10
Nevada	109,000	63,000	70.6	25
New Jersey	2,120,000	1,194,000	88	8
New Mexico	5,848,000	1,701,000	41	10
New York	12,000,000	4,193,000	76.5	25
North Dakota	430,000	21,500	70	54
North Carolina	19,341,400	10,288,000	91.6	10-15
Ohio	5,396,000	1,614,300	94.5	10
Oklahoma	5,600,000	Unknown	90	13
Oregon	26,613,000	6,011,000	38.7	80
Pennsylvania	15,000,000	5,267,000	78	9
Rhode Island	430,000	195,000	92	5
South Carolina	12,886,345	8,933,000	91	55
South Dakota	1,900,000	120,000	28	25
Tennessee	13,432,400	3,442,000	89	40
Texas	12,294,442	Unknown	93.2	93.8
Utah	3,854,000	371,000	10.2	25
Vermont	4,163,522	Unknown	90	30
Virginia	15,450,000	2,830,000	90.1	25
Washington	19,490,000	8,483,000	50	60
West Virginia	11,423,000	8,097,800	90	15
Wisconsin	15,396,000	5,127,000	41.4	27
Wyoming	4,900,000	389,000	17.7	16.8

Amitrole-T, and phenoxy herbicides. Atrazine has been successfully used in preparing sites for reforestation in the Douglas fir region in Oregon and Washington.

Application of the herbicides is generally done by aerial spraying since this method is effective, inexpensive, and suitable to mountainous terrain and inaccessible areas. Phenoxy herbicides are applied at the rate of 2 to 4 lb in volumes of 4 to 10 gal. of spray per acre. The carriers used are water, oil, or oil-in-water. Amitrole, atrazine, and similar herbicides are applied at rates of 2 to 4 lb/acre, using water as the carrier.

Control during establishment of the forest species involves destroying weeds and grasses which compete with the saplings for moisture, and suppressing the foliage (overstory) of other trees to prevent shading and damaging mechanical action. Weeds and grasses are generally controlled with simazine or atrazine applied at the rate of 4 to 6 lb/acre. Overstory control depends primarily on the species being grown and the woody associates requiring foliage suppression.

Established stands of conifers encounter the problem of encroachment by undesirable hardwoods. These hardwoods compete with the conifers for growth factors such as moisture, nutrients, and light. Hardwood control in conifer forests in the U.S. is most frequent in the pine stands in the South, Douglas fir and pine in the West, pine in the Great Lakes region, and pine and spruce in the Northeast. Silviculturally, the release or weeding operation is considered selective, in that methods used are designed to restrict the growth of competing undesired species, thus releasing the favored species with little damage.

Methods used to control the weedy hardwoods with herbicides include foliar applications, basal-bark treatment, and cut-surface treatments. The cut-surface is a combination of mechanical and chemical techniques generally classified as cut stump, frill-girdle, and tree injection. Foliar applications are normally applied by helicopter or airplane. Basal-bark treatment involves spraying the bark surface above the groundline, and is used as a selective control of low-density scattered hardwoods. The cut-stump method is merely cutting the tree down and spraying the stump. Frill-girdle treatment involves cutting through the bark around the circumference of a tree with an axe, and then herbicides are applied in the cut surface immediately after girdling the tree. Tree injection is accomplished by driving a chisel blade or automatic-metering hatchet into the xylem of the tree, and then injecting the herbicide into the tree with a special device.

The methods and the herbicides normallly used are listed below:

Method	Herbicides
Foliar	2,4-D
Basal-bark	2,4-D
Cut-stump	2,4-D, Ammonium Sulfamate, Chlorophenoxy
Frill-girdle	2,4-D, Ammonium Sulfamate, Sodium Arsenite
Tree injection	2,4-D

Control of low-value conifers and thinning of dense stands is also desirable at times. Herbicide selectivity is ruled out in this case, since the low-value trees are normally the same species as the desired trees. Hand-cutting is often used. Herbicides may be employed using the cut-surface treatments, or substituted ureas (such as fenuron) are used as spot treatments in thinning operations.

Control of undesirable vines and undergrowth is difficult. Herbicides show the best promise in eliminating vines since mehcanical means of cuttin, mowing, or disking them merely stimulate a resurge of stems through sprouting or root-suckering.

Firebreaks are placed in commercial forests to prevent total destruction by fire. They are prepared by removing all flammable material from strips of suitable width. If weed and brush accumulation must be controlled, 2,4-D is sometimes employed along with mowing.

C. Discussion of the Usage of the 25 Intensive-Study Pesticides

Not all of the 25 intensive-study pesticides are used in the industrial-commercial-institutional sector. Those presently having little or no use are:

Insecticides - Carbofuran, Disulfoton, Methyl parathion, Parathion

Herbicides - Alachlor, Trifluralin

Fungicides and Wood Preservatives - Captan, Maneb

The pesticides used in this sector are listed in Table XIX along with the total quantities consumed by industry, commerce, and institutions in 1972.

TABLE XIX

PESTICIDE USE IN THE INDUSTRIAL, COMMERCIAL, AND INSTITUTIONAL SECTOR[a]

Pesticide	Total
Insecticides	
Aldrin	1.7
Carbaryl	1.0
Chlordane	6.5
Diazinon	1.2
Malathion	4.0
Toxaphene	1.0
Herbicides	
Atrazine	1.7
Bromacil	2.3
2,4-D	6.0
Diuron	3.8
MSMA	4.0
Sodium Chlorate	19.0
Fungicides and Wood Preservatives	
Creosote	970
Pentachlorophenol and sodium salt	47.5
Fumigants	
Methyl bromide	14.0
p-Dichlorobenzene	14.0
Special Category	
Organotin compounds	0.8

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[a] Data in millions of pounds, AI.

Source: MRI estimates.

VI. USE OF PESTICIDES BY GOVERNMENTAL AGENCIES

A. Introduction

Nearly 200 different pesticides are used by agencies of the government at the federal, state and local levels. These pesticides are used for a wide range of pest control purposes, including public health, disease control, land and water management, and rodent or predator control. However, information on the kinds and amounts of pesticides being used by governmental agencies has not been available. The objectives of this task of the present study were to compile information on use of all pesticides at these three levels of government, to estimate the total use for the 25 intensive-study pesticides and the geographical distribution of use where this use is significant. Examples of the kinds of pesticide use that were anticipated for each of the three governmental levels are shown in Table XX.

B. Federal Government Agencies

Pesticides are used by dozens of different agencies of the federal government. Under current regulations each federal agency must request approval for proposed pesticide usages each year. They do this by submitting to the Federal Working Group on Pest Management, a detailed form (WGP Form 1) that states the amounts each kind of pesticide proposed for specific applications. The form is supplemented (WGP Form 2) by descriptions of the reasons why the pesticides are needed, the methods of application, precautions that will be taken, alternative methods of control, and monitoring procedures. A sample page from WGP Form 1 is shown in Figure 1.

The Federal Working Group on Pest Management (FWGPM) has cooperated in the present study and has supplied quantitative information on proposed pesticide usage by all agencies of the federal government for 1972. The FWGPM reviewed all the WGP Form 1's in its files and compiled for each individual pesticide information on the agencies that proposed to use it, on the state or region that the request originated in, and on the actual amounts of active ingredient that the agency wished to apply. The FWGPM supplied this information in a standard form for 188 individual pesticides, as shown for the insecticide, Abate®, in Table XXI.

The 188 pesticides are listed alphabetically in Table XXII together with the total quantities of active ingredients. Note that these data are for proposed usage--not actual amounts used during 1972--and represent a maximum amount. That is, an agency might use less than the proposed amount for some reason, but it if wished to use a greater amount, it would ordinarily amend its application during the year and this added amount would be included in Table XX.

TABLE XX

TYPICAL PESTICIDE USES BY GOVERNMENTAL AGENCIES

Federal Government Agencies

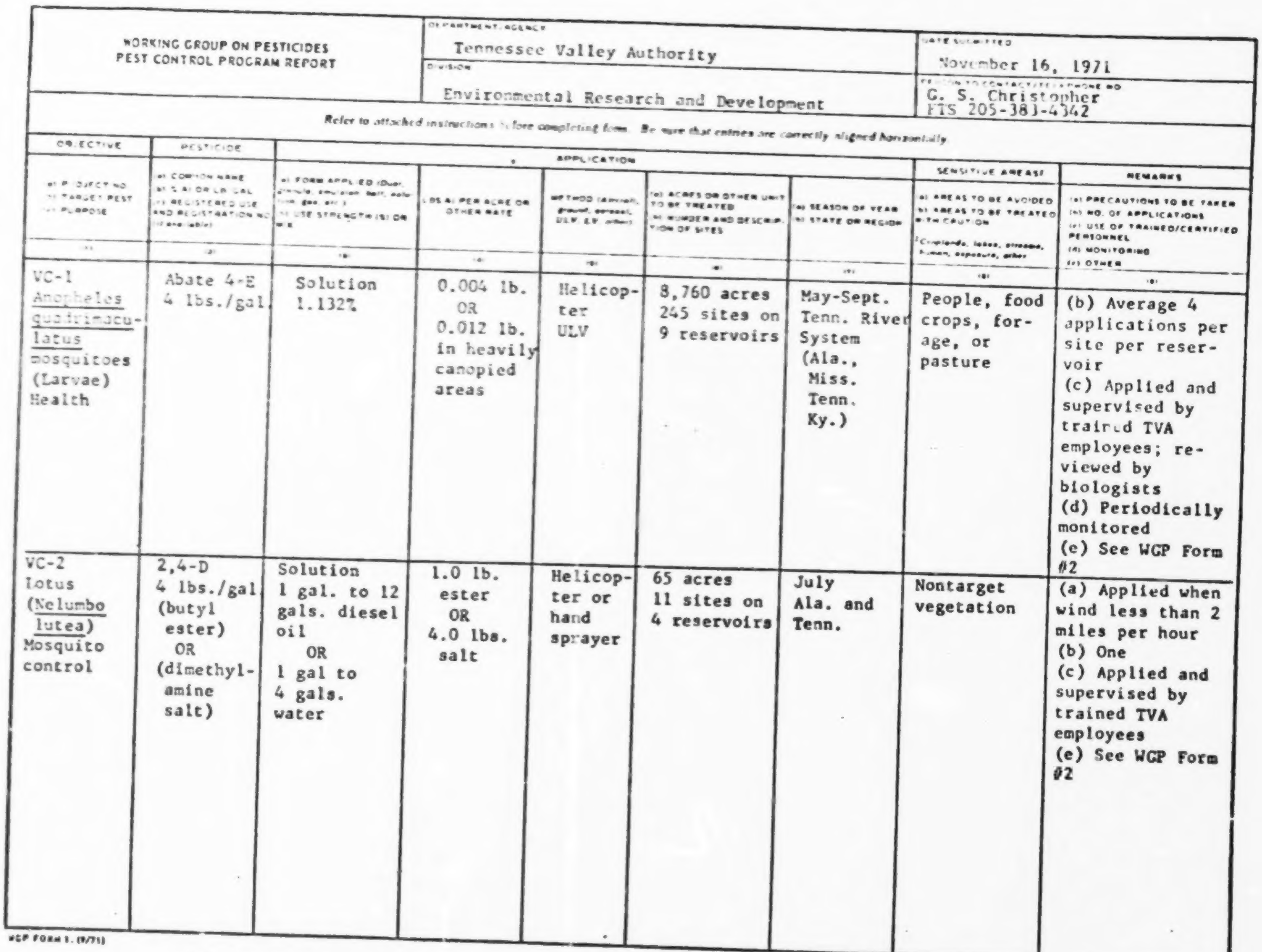
Public health programs of pest control
National forests, rangelands, parks
Military bases - insect and weed control; personnel protection; protection of military buildings, supplies, food stocks, etc.
Pest control along coastal waters and navigable rivers
Predator control programs
Other pest control, quarantine, eradication or vector control programs
Protection of government owned buildings, facilities and goods or supplies from pests (excluding pest control contracted to commercail applicators, which will be covered in Task 3)

State Governmental Agencies

State owned buildings and grounds
Weed control along highways
Insect and weed control in state parks and lands
Water drainage district insect and weed control programs
Fish hatcheries
Special state pest control programs

Municipal, City, County and Other Local Agencies

City streets and boulevards, county roads
Public health programs including mosquito abatement
Park spray programs, particularly for Dutch elm disease, insect and weed control
City or county owned buildings and grounds
Other local pesticide use programs



WORKING GROUP ON PESTICIDES PEST CONTROL PROGRAM REPORT	DEPARTMENT/AGENCY Tennessee Valley Authority	DATE SUBMITTED November 16, 1971
	DIVISION Environmental Research and Development	PERSON TO CONTACT/TELEPHONE NO. G. S. Christopher FTS 205-383-4342

Refer to attached instructions before completing form. Be sure that entries are correctly aligned horizontally.

OBJECTIVE	PESTICIDE	APPLICATION					SENSITIVE AREAS¹	REMARKS
(a) PROJECT NO. (b) TARGET PEST (c) PURPOSE	(a) COMMON NAME (b) % A.I. OR LB/GAL (c) REGISTERED USE AND REGISTRATION NO. (if available)	(a) FORM APPLIED (Dust, granule, emulsion, bait, solution, gas, etc.) (b) USE STRENGTH (S) OR ...	LBS A.I. PER ACRE OR OTHER RATE	METHOD (Aircraft, ground, aerosol, ULV, LV, other)	(a) ACRES OR OTHER UNIT TO BE TREATED (b) NUMBER AND DESCRIPTION OF SITES	(a) SEASON OF YEAR (b) STATE OR REGION	(a) AREAS TO BE AVOIDED (b) AREAS TO BE TREATED WITH CAUTION ¹Croplands, lakes, streams, human, exposure, other	(a) PRECAUTIONS TO BE TAKEN (b) NO. OF APPLICATIONS (c) USE OF TRAINED/CERTIFIED PERSONNEL (d) MONITORING (e) OTHER
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VC-1 *Anopheles quadrimaculatus* mosquitoes (Larvae) Health	Abate 4-E 4 lbs./gal.	Solution 1.132%	0.004 lb. OR 0.012 lb. in heavily canopied areas	Helicopter ULV	8,760 acres 245 sites on 9 reservoirs	May-Sept. Tenn. River System (Ala., Miss. Tenn. Ky.)	People, food crops, forage, or pasture	(b) Average 4 applications per site per reservoir (c) Applied and supervised by trained TVA employees; reviewed by biologists (d) Periodically monitored (e) See WGP Form #2
VC-2 Lotus (*Nelumbo lutea*) Mosquito control	2,4-D 4 lbs./gal (butyl ester) OR (dimethylamine salt)	Solution 1 gal. to 12 gals. diesel oil OR 1 gal to 4 gals. water	1.0 lb. ester OR 4.0 lbs. salt	Helicopter or hand sprayer	65 acres 11 sites on 4 reservoirs	July Ala. and Tenn.	Nontarget vegetation	(a) Applied when wind less than 2 miles per hour (b) One (c) Applied and supervised by trained TVA employees (e) See WGP Form #2

WGP FORM 1 (9/71)

Figure 1 - Sample Page of a Governmental Agency Report to FWGPM

TABLE XXI

SAMPLE PESTICIDE SUMMARY FROM FWGPM[42]

Pesticide: Abate

Total pounds used nationwide: 26,934.8

Agency	State	Region	Pounds AI Used	Agency Total (lb)
Air Force	--	Canal Zone	8	508
Air Force	Alabama, Georgia, Mississippi, Texas	--	500	--
Army - Civil Works	Maryland, Delaware	--	8.1	8.1
Army - Facilities Engineering	North Carolina, Virginia	--	66.5	211.5
Army - Facilities Engineering	--	CONUS	55	--
Army - Facilities Engineering	New Jersey	--	90	--
Navy	--	Southeast U.S.	280	460
Navy	--	East, South, Southwest U.S.	180	--
District of Columbia	Washington, D.C.	--	2,000	2,000
Sport Fisheries and Wildlife	Massachusetts	--	3.5	21,752.5
Sport Fisheries and Wildlife	New Jersey	--	1,184	--
Sport Fisheries and Wildlife	New Jersey	--	234	--
Sport Fisheries and Wildlife	New Jersey	--	1,123	--
Sport Fishereis and Wildlife	Delaware	--	15,451	--
Sport Fisheries and Wildlife	Delaware	--	142	--
Sport Fisheries and Wildlife	Delaware	--	1,170	--
Sport Fisheries and Wildlife	Delaware	--	2,435	--
Sport Fisheries and Wildlife	Nebraska	--	5	--
Sprot Fisheries and Wildlife	Utah	--	5	--
National Park Service	New York	--	22.7	251.7
National Park Service	New York	--	229	--
TVA	Kentucky, Alabama, Tennessee, Mississippi	--	280	280
Bureau of Indian Affairs	--	--	1,428	1,428
Forest Service	--	--	35	35

TABLE XXII

PESTICIDE USAGES PROPOSED BY FEDERAL GOVERNMENT AGENCIES, 1972 [a/]

Pesticide	Lb AI	Pesticide	Lb AI
Abate	26,935	CDEC	8
Acrolein	953	Chelated copper sulfate	171,398
Alachlor	883	Chlordane	1,668,454
Aldicarb	3,750	Chlorea	14,199
Aldrin	965	Chlorflurecol	70
Aluminum phosphide	6,000	Chlorobenzilate	27
AMA	900	Chlorophacinone	4
Amitrol	31,541	Chlorothalonil	78
Ammate	206,733	Chlorpyrifos	2,035
Anthraquinone	403	Ciodrin	56
Antymycin	153,355	Copper sulfate	3,931,415
Aromatic oils	806,110 gal.	Coumaphos	5,466
Atrazine	65,803	Cyclohexamide	221
Avitrol	501	Cyprex	26
Azinphosmethyl	4,404	Dacamine	200
Bacillus thuringiensis	131	Dalapon	96,914
Barban	96	Dazomet	458
Bayluscide	1,900	DCPA	8,279
Benefin	11,060	DDT	147,275
Benomyl	1,162	Def	5,343
Benzabor	1,280	Demeton	520
BHC	302,338	Diazinon	1,660,358
Borate and borate mixtures	266,600	Dicamba	15,294
Borax	68	Dichlobenil	2,811
Bromacil	46,227	Dichloropropene	207,000
Bromoxynil	219	Dichlorvos	6,131
BUX	150	Dicofol	2,783
Cacodylic acid	32,323	Difolaton	29
Cadminate	871	Dimethoate	10,174
Calcium arsenate	846	Dinocap	2,518
Calcium cyanide	1,863	Dioxathion	438
Calcium hypochlorite	1 oz	Dinitrophenol	1
Captan	7,488	Diphacinone	35
Carbaryl	2,187,950	Diphenamid	278
Carbofuran	6	Diquat	11,052
Carbon disulfide	37 gal.	Disulfoton	1,921
Carbophenethion	37,154	Diuron	69,094
		DNBP	1,800

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a/ Data adapted from Ref. 42.

TABLE XXII (Continued)

Pesticide	Lb AI	Pesticide	Lb AI
DSMA	4,230	Mirex	106,092
Dylox	100,023	Monitor	1,800
Dyrene	14	Monuron	153,098
Endosulfan	190	Monuron-TCA	8,173
Endothall	7,114	Morestan	100
EPTC	374	MSMA	40,797
Ethion	905	Naled	120,163
Ethylene Dibromide	5	Napthalene	7,567
Ethylene Dichloride	60,903	Nemagon	6,020
Ethylene Oxide	31	Nicotine Sulfate	1
Famphur	98	Norbormide	3
Fenac	267	Norea	196
Fenamine	1,500	Paradichlorobenzene	6 gal.
Fensulfothion	7,350	Paraquat	4,181
Fenthion	32,674	Parathion	1,504
Fenuron Tea	17	Paris Green	19,088
Ferbam	4,463	PCNB	72
Flit MLO	256,933	Pentac	4
Folex	5,175	Pentachlorophenol	0.2
Folpet	5,729	Phorate	5
Fore	1,381	Picloram	76,495
Furadan	275	Pindone	22
Fumarin	17	Polyram	30
Gardona	1,280	Prolin	2
Glytac	2,090	Prometone	43,719
Heptachlor	13,077	Propachlor	6,719
Imidan	450	Propanil	342
Kepone	3,651	Propazine	108
Kobun	25	Propoxur	14,303
Kromad	273	Pyrethrum	214
Lampricide	101,300	Red Squill	12,075
Lethane	30 fl oz	Ronnel	293
Lead Arsenate	167	Rotenone	22,283
Lime Sulfur	2,138	Ruelene	1,050
Lindane	3,103	Silvex	96,410
Malathion	2,479,357	Simazine	34,875
Maneb	21	Sodium Arsenite	4
MCPP	8,002	Sodium Chlorate	161,328
Metaldehyde	2,904	Sodium Chromate	100
Methoxychlor	30,908	Sodium Fluosilicate	123
Methyl Bromide	44,769	Sodium Monofluoroacetate	10
		Streptomycin	0.5
Methyl Bromide and Chloropicrin	46,330	Strychnine	15,486
Methyl Parathion	6,063	Sulfuryl Floride	600
Mevinphos	333		

TABLE XXII (Concluded)

Pesticide	Lb AI
Sulfur	17,800
Tandex	29,060
TCA	89,949
Terbacil	240
Terrazol	13
Tetradifon	16
Thiodan	1,330
Thiram	13,136
Toxaphene	49,684
Trifluralin	937
2,4-D	2,637,971
2,2-D	300
2,4-DP	4,019
2,4,5-T	344,219
2,3,6-TBA	3,982
Vitavax	0.1
Vorlex	120,000
Warfarin	200
Zectran	75,001
Zinc Phosphide	2,449
Zineb	2,388
Ziram	647

Fifteen of the pesticides listed in Table XXII had proposed usages of more than 150,000 lb each. Table XXIII lists the amounts of each of these 15 pesticides that were used by specific governmental agencies. Note that these data include usage outside the continental United States;* e.g., nearly all of the copper sulfate is used in Panama. The pesticides in Table XXI include six of our 25 intensive-study pesticides. However, all but one of the intensive-study pesticides had some use proposed by federal governmental agencies.

C. State Government Agencies

Pesticides are used by several different agencies of state government, but few states have compiled and published data on this usage. On the present program, a survey has been made of pesticide usage by state agenices in the 48 contiguous states. The survey procedure was as briefly described below.

A list of the purchasing agents** for each state was obtained from the Book of the States*** and a request for information was sent to each. The request included a standard form on which pesticide usage could be recorded. Also included was a sample copy of a completed form. Purchasing departments that could not furnish the requested data were asked to forward our letter to the appropriate agencies or to provide contacts for us in those agencies. Copies of the letter, the sample form and the list of purchasing agents are given in Appendix F. A follow-up letter was sent to 26 purchasing agents that had not replied within a reasonable time. An additional 19 letters were sent to specific departments suggested by the purchasing agents.

Response to the survey was good; data were eventually obtained from 35 of the 48 states (73%). The amount and quality of the data varied from state to state, however, for several reasons. In some states the purchasing department keeps complete records of all pesticides used by state agencies, while in others some or many of the state agencies may purchase pesticides directly, and a central record file is either incomplete or nonexistent. Thus, the data reported represent minimum amounts purchased, but time did not permit a determination of the degree of underreporting that may have occurred. In addition, the data reported were not always in

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* The FWGPM data in some cases may indicate the location of the purchasing agency instead of the point of application.

** The title of this position varies in some states, e.g., it may be Director of Supply, or Director of Purchasing and Property for Printing, Service, Contacts, etc.

*** Published by the Council of State Governments.

TABLE XXIII

AMOUNTS OF MAJOR PESTICIDES USED BY INDIVIDUAL FEDERAL GOVERNMENT AGENCIES

Pesticide	Agency[a]/	Lb, AI
Ammate	Army - Civil Works	154,500
	AEC	37,500
	Air Force	7,150
	NASA	750
	Army - Facilities Engineering	1,596
	Bonneville Power Administration	1,260
	National Park Service	1,040
	Forest Service	876
	Bureau of Land Management	200
	TVA	1,860
	Total	206,732
Antymycin	Sport Fisheries and Wildlife	153,335
	Forest Service	20
	Total	153,355
BHC	Sport Fisheries and Wildlife	294,030
	Forest Service	3,000
	GSA	2,200
	National Park Service	1,742
	NASA	665
	APHIS	653
	Army - Civil Works	44
	D.C., Government	4
	Total	302,338
Borate and Borate Mixtures	FAA	200,000
	Bureau of Reclamation	62,822
	Air Force	1,500
	Army - Facilities Engineering	1,000
	Bureau of Indian Affairs	120
	Panama Canal Company	1,158
	Total	266,600
Dichloropropene	APHIS	135,000
	Agriculture Research Service	72,000
	Total	207,000

Pesticide	Agency[a]	Lb, AI
Carbaryl	APHIS	1,249,278
	Air Force	713,179
	Forest Service	100,410
	Sport Fisheries and Wildlife	35,258
	Army - Facilities Engineering	20,000
	AEC	18,844
	Navy	17,857
	Panama Canal Company	15,282
	Bureau of Land Management	4,500
	U.S. Soldiers Home	3,000
	Army - Civil Works	2,750
	Bureau of Indian Affairs	1,624
	Agriculture Research Service	1,506
	GSA	1,484
	FAA	1,200
	NIH	936
	NASA	380
	Bureau of Prisons	271
	D.C., Government	100
	U.S. Postal Service	67
	TVA	14
	National Park Service	8
	Maratime Administration	3
	Total	2,187,951
Chlordane	Air Force	1,069,093
	APHIS	204,300
	Army - Facilities Engineering	123,163
	NASA	93,688
	Army - Civil Works	61,594
	National Park Service	56,500
	Panama Canal Company	22,102
	GSA	14,569
	Navy	7,025
	Bureau of Prisons	6,325
	FAA	2,248
	Sport Fisheries and Wildlife	1,644
	Department of Transportation - Coast Guard	1,215
	D.C., Government	1,000

Source: Data adapted from Ref. 42.

TABLE XXIII (Continued)

Pesticide	Agency[a]	Lb, AI
Chlordane (Concluded)	Bureau of Indian Affairs	880
	TVA	752
	AEC	699
	U.S. Soldiers Home	576
	Forest Service	555
	NIH	375
	U.S. Postal Service	100
	FHA	40
	FDA	12
	Total	1,668,455
Copper Sulfate	Panama Canal Company	3,906,114
	Bureau of Reclamation	19,559
	Sport Fisheries and Wildlife	4,471
	Bureau of Indian Affairs	654
	AEC	433
	Navy	126
	Forest Service	59
	Total	3,931,416
2,4-D	Army - Civil Works	992,469
	Forest Service	838,737
	Veterans Administration	200,000
	Bureau of Land Management	149,950
	TVA	147,556
	Sport Fisheries and Wildlife	93,812
	Bureau of Indian Affairs	69,572
	Bonneville Power Administration	52,680
	Bureau of Reclamation	36,443
	GSA	28,940
	NASA	11,108
	APHIS	8,643
	D.C., Government	4,000
	Air Force	1,769
	AEC	900
	Navy	440
	Coast Guard	300
	FAA	216
	U.S. Soldiers Home	200
	Bureau of Prisons	150
	Agriculture Research Service	56
	FHA	20
	Smithsonian Institute	6
	U.S. Postal Service	5
	Total	2,637,971
Diazinon	GSA	740,991
	Air Force	620,562
	Army - Facilities Engineering	271,555
	Coast Guard	11,229
	Army - Civil Works	3,958
	Bureau of Reclamation	3,293
	Panama Canal Company	1,954
	D.C., Government	1,680
	Veterans Administration	1,577
	National Park Service	1,026
	Bureau of Prisons	807
	Indian Health Service	609
	AEC	250
	St. Elizabeths Hospital	245
	Bureau of Indian Affairs	196
	NIH	182
	NASA	79
	Smithsonian Institute	38
	U.S. Postal Service	33
	APHIS	30
	FDA	26
	FAA	24
	Maritime Administration	8
	Department of Transportation - St. Lawrence Seaway	3
	Forest Service	1
	U.S. Soldiers Home	1
	Department of Transportation - Transportation Systems Center	1
	Total	1,660,358
Flit MLO	Sport Fisheries and Wildlife	200,566
	National Park Service	28,107
	Army - Civil Works	14,760
	NASA	13,500
	Total	256,933

TABLE XXIII (Concluded)

Pesticide	Agency[a]	Lb, AI
Malathion	APHIS	1,784,480
	D.C., Government	436,877
	Navy	90,320
	Army - Facilities Engineering	68,474
	Air Force	32,673
	Army - Civil Works	22,356
	Sport Fisheries and Wildlife	12,815
	Bureau of Indian Affairs	10,751
	Department of Transportation - Coast Guard	4,766
	NASA	3,812
	Bureau of Prisons	2,163
	FAA	2,046
	Indian Health Services	1,888
	Agriculture Research Service	1,500
	Forest Service	1,383
	GSA	1,377
	U.S. Soldiers Home	523
	St. Elizabeths Hospital	451
	NIH	225
	Bureau of Reclamation	170
	Panama Canal Company	126
	Bureau of Land Management	62
	Veterans Administration	50
	FHA	24
	Smithsonian Institute	15
	TVA	11
	National Park Service	10
	U.S. Postal Service	6
	Maritime Administration	2
	AEC	2
	Total	2,479,358

Pesticide	Agency[a]	Lb, AI
Monuron	FAA	54,244
	Army - Civil Works	46,040
	Bonneville Power Administration	25,000
	Air Force	17,760
	Bureau of Reclamation	5,603
	AEC	2,800
	Bureau of Indian Affairs	1,080
	Veterans Administration	450
	GSA	123
	Total	153,100
Sodium Chlorate	FAA	56,469
	Bonneville Power Administration	49,500
	Air Force	33,976
	Army - Civil Works	8,166
	Sport Fisheries and Wildlife	7,840
	NASA	2,220
	Forest Service	1,535
	Bureau of Reclamation	1,136
	TVA	347
	Bureau of Indian Affairs	139
	Total	161,328
2,4,5-T	Forest Service	258,481
	FHA	31,250
	TVA	24,168
	APHIS	11,525
	D.C., Government	7,520
	Bonneville Power Administration	5,370
	Air Force	3,600
	Navy	940
	Army - Civil Works	829
	Agriculture Research Service	500
	Sport Fisheries and Wildlife	36
	Total	344,219

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[a] AEC - Atomic Energy Commission
APHIS - Animal and Plant Health Inspection Service, USDA
FAA - Federal Aviation Administration, Department of Transportation
FDA - Food and Drug Administration
FHA - Federal Highway Administration, Department of Transportation
GSA - General Services Administration
NASA - National Aeronautics and Space Administration
NIH - National Institutes of Health
TVA - Tennessee Valley Authority

terms of pounds of active ingredients; e.g., in some cases only the number of gallons purchased were noted. In such cases we have calculated the amount of AI based on the concentrations most frequently reported by other state or city agencies.

Special mention must be made of California; that state did not supply data on pesticide use by state agencies, but instead referred us to the California Department of Agriculture's Pesticide Use Report for 1972. This report tabulates data on usage in the state* and in some cases by the agency reporting. Based on the data in this report we have estimated pesticide use by California state agencies. In this case, our data are probably biased on the high side because usage by some nonstate agencies were included,** and the end-use was not always clear. On the other hand, some use on state premises may have been neglected, e.g., applications of pesticides on state lands or premises by private operators.

The total amounts reported by individual states for each of the 25 intensive-study pesticides are listed in Table XXIV; Figures 2, 3 and 4 illustrate the geographical distribution of this reported use for insecticides, herbicides and other pesticides respectively. Additional data on other pesticides with substantial use by state agencies are discussed in Section F of this chapter.

Herbicides and insecticides are the principal pesticides used by state agencies. Herbicides are used primarily for vegetation control along highways, and insecticides are used for public health purposes. Lesser amounts of herbicides are used in the maintenance of state government buildings and grounds, state parks, and state schools and universities. Rodenticides are also used to control pests which pose potential health hazards. Pesticide usage was largely by the following departments: (1) highway; (2) transportation; (3) health; (4) park and recreation; (5) forestry; and (6) fish, game and wildlife. The two most predominantly used pesticides were malathion and 2,4-D.***

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* The results of the California report are presented in Appendix B.

** Categories included in the California report were: state highways, water resources, water areas, vector control, University of California, county roads, county or city parks, county agricultural commissioner, and "other agencies" (excluding federal agencies, city agencies, school districts and irrigation districts).

*** Reported 2,4-D usage was 321,000 lb AI, although sodium chlorate use was greater, 341,000 lb AI. However, California usage of sodium chlorate was 337,000 lb which accounted for 99% of the total. (California data are discussed separately below.) Therefore, 2,4-D is the more representative pesticide nationwide.

TABLE XXIV

USAGE OF 25 INTENSIVE-STUDY PESTICIDES REPORTED BY STATE GOVERNMENT AGENCIES

(Pounds Active Ingredient)

	Arkansas	California	Colorado	Connecticut	Florida	Georgia	Idaho	Illinois	Indiana	Kansas	Kentucky	Maine	Maryland	Massachusetts	Minnesota	Montana
Aldrin		4,565														
Carbaryl		5,787		638	13,232			235	15		480			393		
Carbofuran											390					
Chlordane	63	20,692		326			6		20					699		
Diazinon		9,642		104				140	145					59		
Disulfoton		380		5			1					195				
Malathion		13,437		1,593	824,795		9	763	105				1,088	90		
Methyl Parathion		421														
Parathion		216														
Toxaphene		2,939							300							
Alachlor		70		320												
Atrazine		68,946		476			4			800	1,400			339	500	344
Bromacil	6,280	96,003			6,180			17	120				1,000			
2,4-D		86,089	1,501	1,948	44,920		120	15,341	4,096	2,300	60		30,087	356	14,136	15,460
Diuron		38,960			22,640			560		80			184		40	
MSMA	70,480	117,946						1,774					1,400			
Sodium Chlorate		337,456								400	2,940					
Trifluralin		6,641			25						70					
Captan		6,550		546					300							
Creosote																
Maneb		158										1,540				
Pentachlorophenol		166														
Tin Compounds																
p-Dichlorobenzene																
Methyl Bromide		65,576			43,28[illegible]											
Totals:	76,823	882,640	1,601	5,956	955,074	0	140	18,830	5,101	3,580	5,280	1,735	33,759	1,597	14,676	15,804

TABLE XXIV (Concluded)

	Nevada	New Hampshire	New Jersey	New Mexico	New York	North Dakota	Pennsylvania	Rhode Island	South Carolina	South Dakota	Tennessee	Texas	Virginia	Washington	Wisconsin	Wyoming	Totals
Aldrin																	4,565
Carbaryl		35	36,960	132,280				61,400					125	175	485		252,240
Carbofuran															610		1,000
Chlordane		29				1			650			10			2		22,498
Diazinon						120			16					26	51		10,303
Disulfoton															180		761
Malathion	1,350	17		19,508		1,943		25	112,875	125	25		950	845	945		980,488
Methyl Parathion																	421
Parathion		12															223
Toxaphene						60											3,299
Alachlor									180	760					1,784		3,114
Atrazine						560			640		1,454			7,448	5,400	104	88,415a/
Bromacil					600					320			340	2,818			113,678
2,4-D				804	24,640	4	17,160				2,180			34,590	18,818	5,960	320,670a/
Diuron					12,640		18,842							29,200	195		123,341a/
MSMA									18				150				191,768
Sodium Chlorate																	340,796
Trifluralin									41		12				15		6,804a/
Captan		14									160				240		7,810
Creosote																	0
Maneb															160		1,858
Pentachlorophenol											132						298
Tin Compounds																	0
p-Dichlorobenzene									607								607
Methyl Bromide									3,224								112,082
Totals:	1,350	107	36,960	152,592	37,880	2,688	36,002	61,425	118,251	1,205	3,963	10	1,565	75,102	28,885	6,064	

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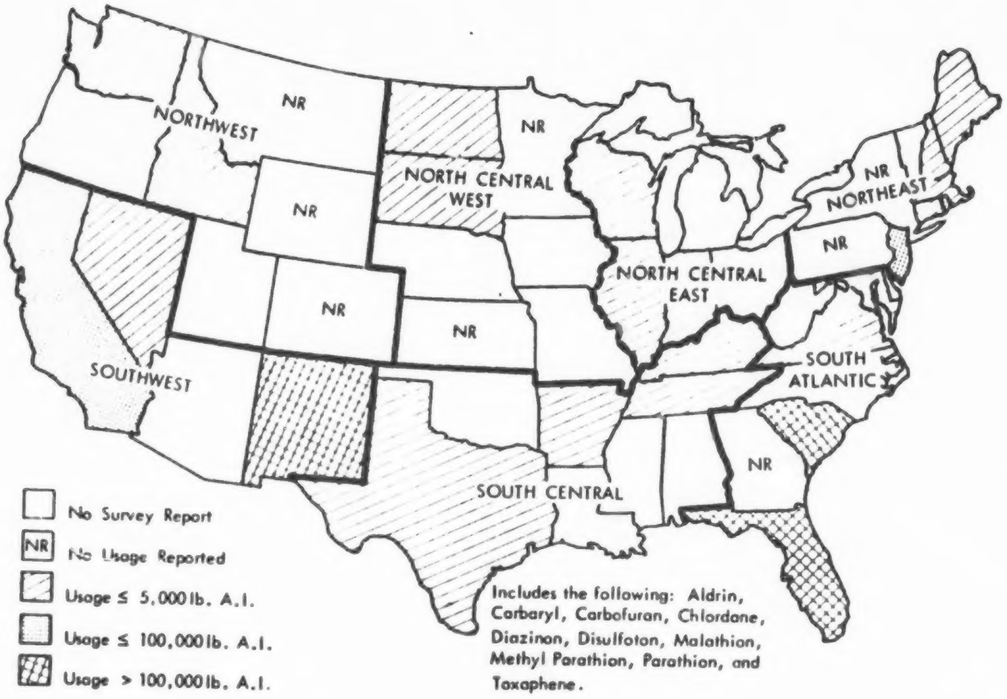
a/ Received too late to be included in the totals:

	Iowa	Michigan	Utah	Totals
2,4-D	3,520	39,300	220	43,040
Atrazine		3,200		3,200
Diuron		3,120		3,120
Trifluralin			34	34

A. INSECTICIDES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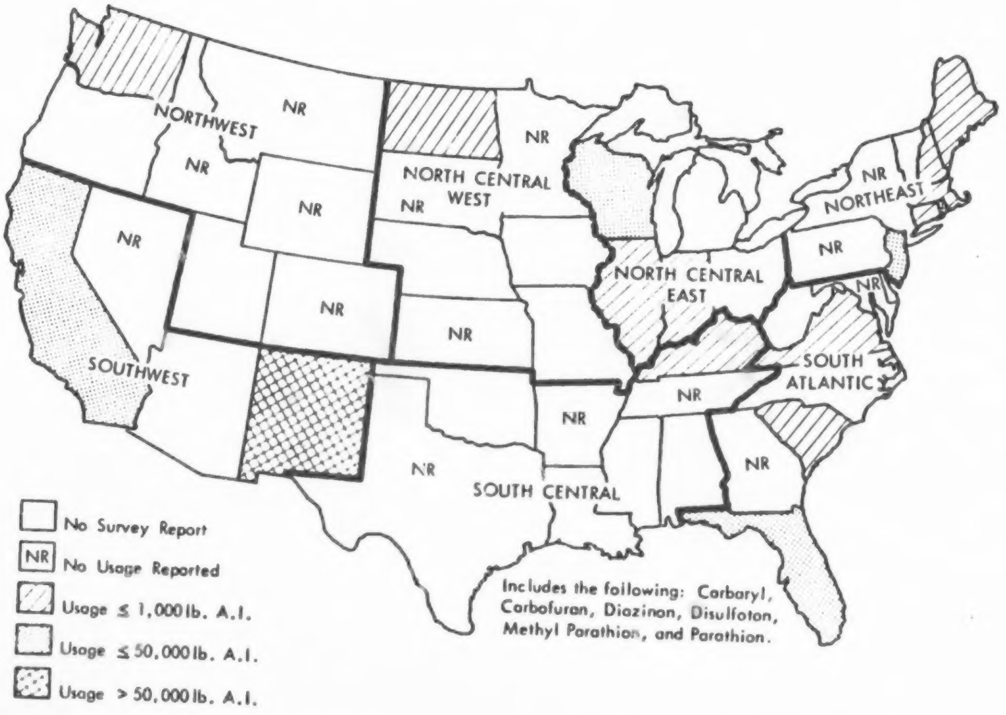
NR
NORTH CENTRAL WEST
NORTH CENTRAL EAST
NORTHEAST
SOUTHWEST
SOUTH CENTRAL
SOUTH ATLANTIC
No Survey Report
NR No Usage Reported
Usage ≤ 5,000 lb. A.I.
Usage ≤ 100,000 lb. A.I.
Usage > 100,000 lb. A.I.

Includes the following: Aldrin, Carbaryl, Carbofuran, Chlordane, Diazinon, Disulfoton, Malathion, Methyl Parathion, Parathion, and Toxaphene.

B. CARBAMATES and ORGANOPHOSPHATES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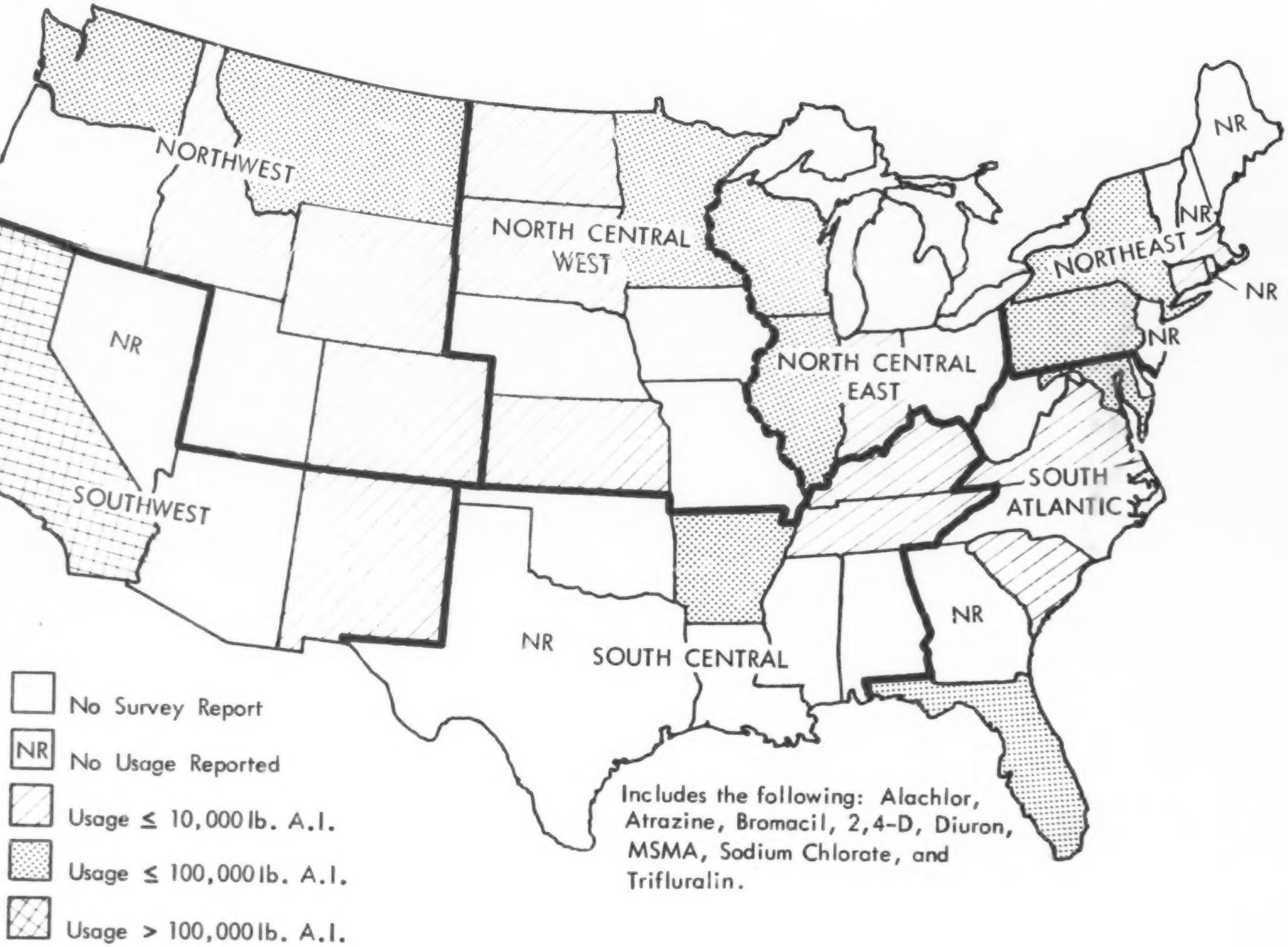
NR
NORTH CENTRAL WEST
NORTH CENTRAL EAST
NORTHEAST
SOUTHWEST
SOUTH CENTRAL
SOUTH ATLANTIC
No Survey Report
NR No Usage Reported
Usage ≤ 1,000 lb. A.I.
Usage ≤ 50,000 lb. A.I.
Usage > 50,000 lb. A.I.

Includes the following: Carbaryl, Carbofuran, Diazinon, Disulfoton, Methyl Parathion, and Parathion.

Figure 2 - Use of Intensive-Study Insecticides by State Agencies

HERBICIDES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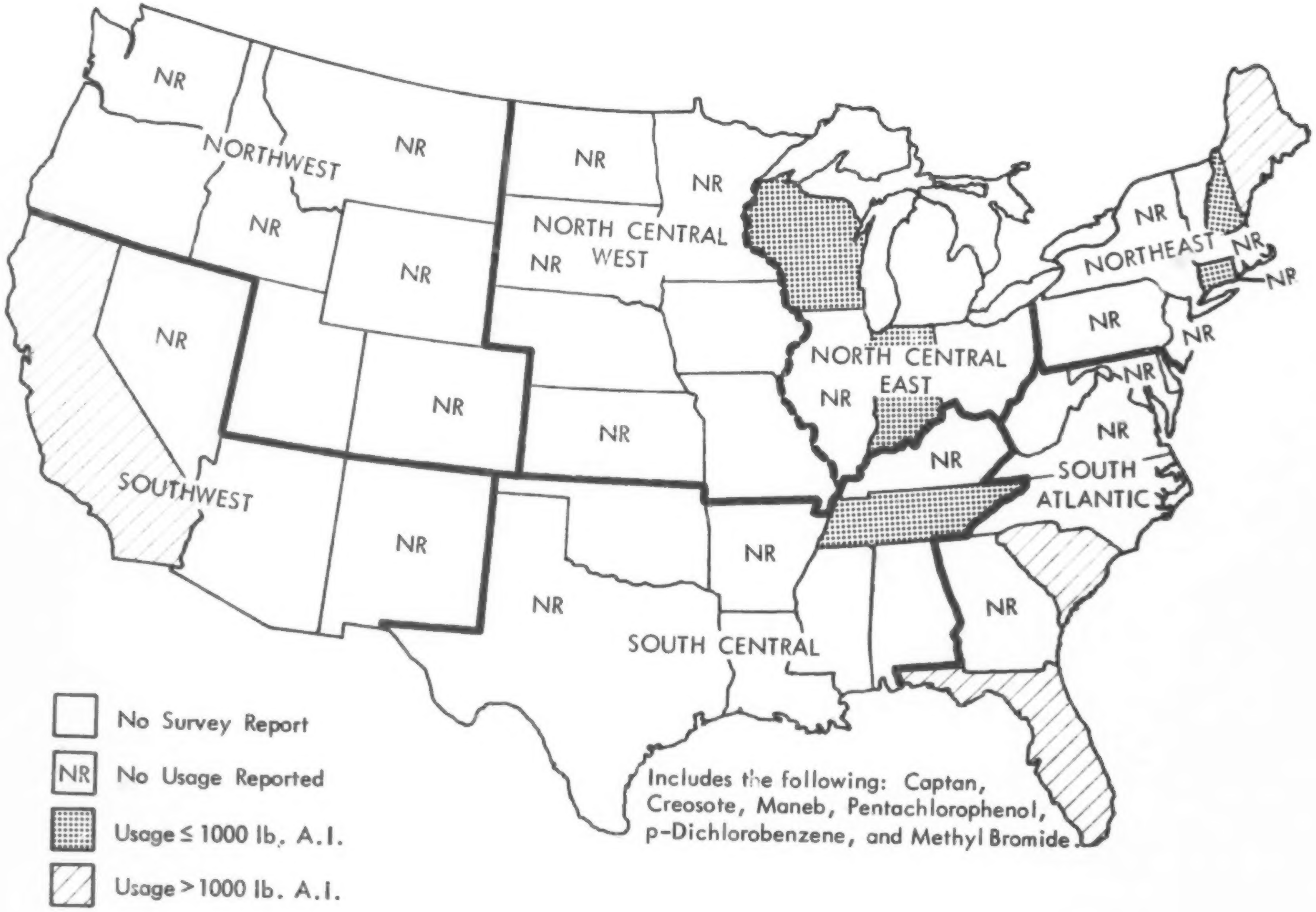
NORTH CENTRAL WEST
NORTH CENTRAL EAST
NORTHEAST
SOUTHWEST
SOUTH CENTRAL
SOUTH ATLANTIC
NR
NR
NR
NR
NR
NR
NR
No Survey Report
NR No Usage Reported
Usage ≤ 10,000 lb. A.I.
Usage ≤ 100,000 lb. A.I.
Usage > 100,000 lb. A.I.

Includes the following: Alachlor, Atrazine, Bromacil, 2,4-D, Diuron, MSMA, Sodium Chlorate, and Trifluralin.

Figure 3 - Use of Intensive-Study Herbicides by State Agencies

FUNGICIDES, WOOD PRESERVATIVES, and FUMIGANTS


NORTHWEST
SOUTHWEST
NORTH CENTRAL WEST
NORTH CENTRAL EAST
NORTHEAST
SOUTH ATLANTIC
SOUTH CENTRAL
NR
☐ No Survey Report
NR No Usage Reported
▦ Usage ≤ 1000 lb. A.I.
▨ Usage > 1000 lb. A.I.

Includes the following: Captan, Creosote, Maneb, Pentachlorophenol, p-Dichlorobenzene, and Methyl Bromide.

Figure 4 - Use of Intensive-Study Fungicides, Fumigants and Preservatives by State Agencies

As indicated in Figures 2, 3, and 4, insecticide and herbicide usages were quite general, but fungicides and wood preservative use was mostly limited to the eastern and southern areas of the continental United States.

In regard to herbicide use, the north central to northwest regions used predominantly atrazine, whereas bromacil was applied to a greater degree in areas with relatively less atrazine usage. In general, herbicides were applied in greater amounts in the less populated areas. In less populated areas there are greater proportions of state and county parks, wildlife preserves and more nonurban highways.* These areas account for the increased herbicide usage in the government maintenance programs in less populated areas.

D. Municipal and Local Government Agencies

Pesticides are used by many agencies of municipal, county and other local government. A survey has been made on this program of pesticide use by 50 municipalities that were selected as being representative of population distribution and geographical location. The cities surveyed are indicated on the map in Figure 5. The survey procedure was similar to that used in the state agency survey; a letter, standard form and sample completed forms were sent to the purchasing department of each of the cities. Follow-up letters were sent to cities that had not responded within a reasonable time, and in a few cases referral contacts were made.

Twenty-two of the cities (44%) responded to our survey; the cities which responded are indicated in Figure 5. We believe that the lower percentage of returns compared to the state surveys reflects the degree to which the city purchasing departments have the requested data available. A preliminary discussion with the purchasing department of Kansas City, for example, revealed that it processed pesticide orders like all others, and did not have the manpower to extract the requested data from its records. This factor appears to account for the poor response from the larger cities; no replies were received from New York, Chicago, Detroit, Houston, Washington, D.C., San Francisco and New Orleans, for example. (However, replies were obtained from Los Angeles, Philadelphia, Baltimore and Dallas.) The purchasing departments which responded either supplied data or forwarded our request to a pertinent department (e.g., departments of parks, health, public recreation, environmental management, etc.) which did supply partial or complete data for city usage. The quantities of

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* See Section E, this chapter, for a further discussion of herbicide usage on highways.

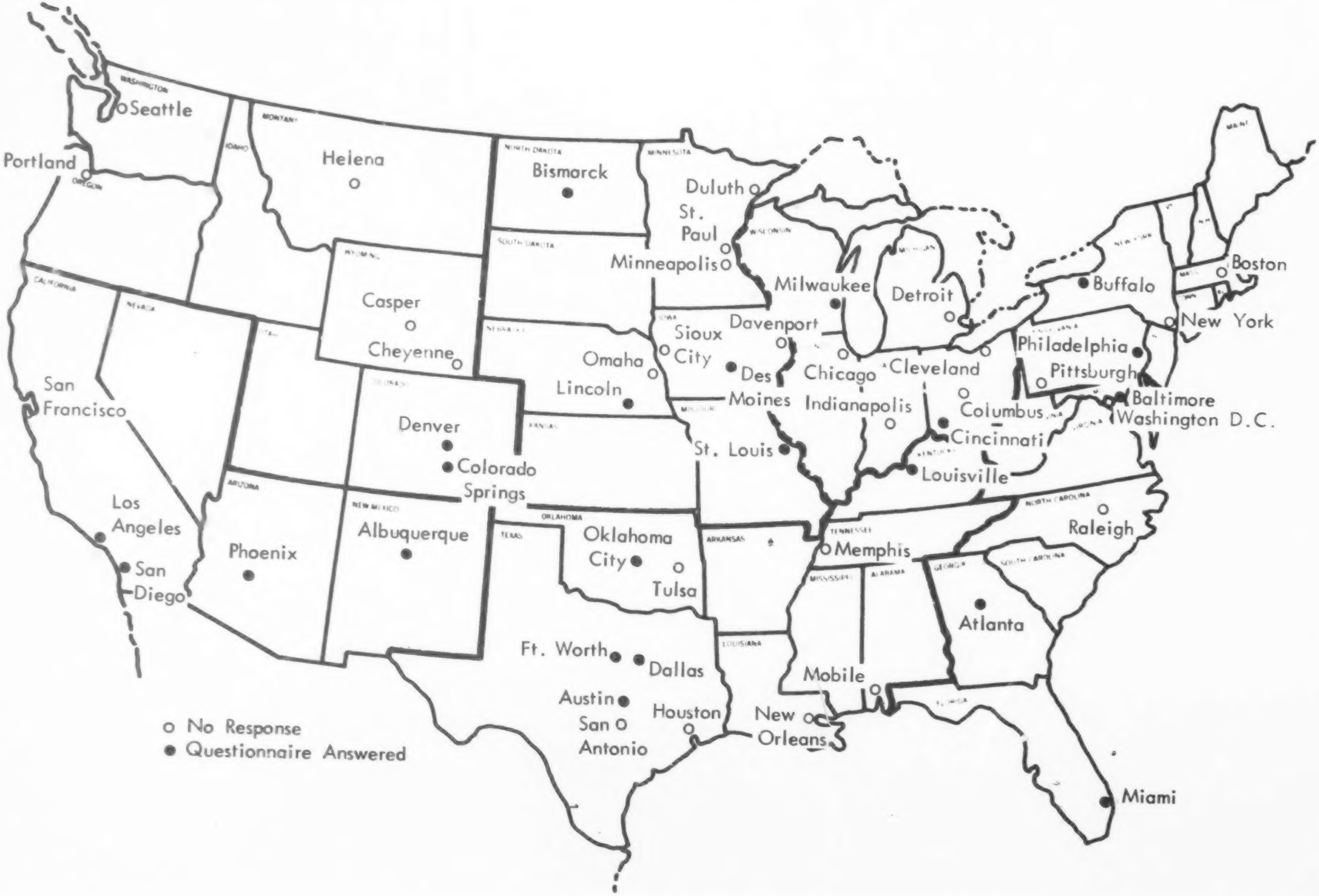
Seattle
Portland
Helena
Bismarck
Duluth
St. Paul
Minneapolis
Milwaukee
Detroit
Buffalo
Boston
New York
Philadelphia
Pittsburgh
Baltimore
Washington D.C.
Casper
Cheyenne
San Francisco
Omaha
Lincoln
Sioux City
Davenport
Des Moines
Chicago
Cleveland
Indianapolis
Columbus
Cincinnati
Louisville
St. Louis
Denver
Colorado Springs
Los Angeles
San Diego
Phoenix
Albuquerque
Oklahoma City
Tulsa
Memphis
Raleigh
Atlanta
Ft. Worth
Dallas
Austin
San Antonio
Houston
New Orleans
Mobile
Miami
○ No Response
● Questionnaire Answered

Figure 5 - Cities Surveyed for Pesticide Usage

pesticides thus reported* represent minimum usages for these 22 cities and the total actual usage could be substantially higher.

Quantities of the 25 intensive-study pesticides that were reported by responding cities are listed in Table XXV. The totals are especially low because of the absence of replies from so many of the large cities (However, Cincinnati, Denver and Louisville reported no substantial use of any of the 25.)

Although the response was relatively poor and the amounts reported were minimums, the survey indicates that the use of pesticides by all municipal governments is probably small compared to pesticide usage by state governments.

Those municipalities which did reply, reported that pesticides were used primarily by the parks and recreation departments (for turf disease and weed control), the health department (for control of rats and mosquitos along with general insect control), and for the maintenance of city owned buildings and grounds. In addition to the fairly consistent herbicide, insecticide, and rodenticide usage, a few cities used fungicides and algaecides, and one had a pest bird program.

The pesticide having the most frequent and largest city usage was malathion. Most of the cities responding had a mosquito control program and employed a malathion spray almost exclusively in this health related program.

E. Governmental Use of Herbicides on Highways and in Water Management

Substantial amounts of herbicides are applied in highway maintenance and water resources management--two areas that are primarily governmental uses, but cross the boundaries between federal, state and local agencies. Special estimates of herbicide usage in these areas have been made on the present** program and are reported here.

Highways: Herbicides are used on highways for three major purposes: (a) safety (e.g., complete vegetation control around signs, guardrails, and at the edge of the pavement; also, brush control around corners or along narrow rural roads); (b) roadbed maintenance (e.g., a pretreatment

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* The pounds of AI was not reported in some instances and was estimated based on the units that were reported and a knowledge of the most frequently used formulations.

** Our consultant, Dr. Dale W. Young, an expert in nonagricultural herbicide use, has compiled the highway herbicide data.

TABLE XXV

USAGE OF 25 INTENSIVE-STUDY PESTICIDES REPORTED BY MUNICIPAL GOVERNMENT AGENCIES

(Pounds Active Ingredient)

	Albuquerque, New Mexico	Atlanta, Georgia	Austin, Texas	Baltimore, Maryland	Bismarck, North Dakota	Buffalo, New York	Cincinnati, Ohio	Colorado Springs, Colorado	Dallas, Texas	Denver, Colorado	Des Moines, Iowa	Ft. Worth, Texas
Aldrin												
Carbaryl												2
Carbofuran												
Chlordane				224					56			183
Diazinon				386			26		32		200	165
Disulfoton												
Malathion	1,120		288	550	75a/	1,500			10,185			131
Methyl Parathion												
Parathion												
Toxaphene												
Alachlor					75a/							
Atrazine												
Bromacil		45										24
2,4-D		92			200			800				
Diuron												
MSMA		360										
Sodium Chlorate												
Trifluralin												
Captan		71										
Creosote												
Maneb												
Pentachlorophenol												
Tin Compounds												
Para-dichlorobenzene												
Methyl Bromide												
Totals	1,120	568	288	1,160	350	1,500	26	800	10,273	0	200	505

TABLE XXV (Concluded)

	Lincoln, Nebraska	Louisville, Kentucky	Los Angeles, California	Miami, Florida	Milwaukee, Wisconsin	Oklahoma City, Oklahoma	Philadelphia, Pennsylvania	Phoenix, Arizona	St. Louis, Missouri	San Diego, California	Totals
Aldrin											0
Carbaryl	1,110		89			120	1,200		74	64	2,659
Carbofuran											0
Chlorodane	280		62	38	4			13		72	932
Diazinon			397	220	10	80			404	80	2,000
Disulfoton											0
Malathion	2,500		24		20	35	500		985		17,913
Methyl Parathion											0
Parathion											0
Toxaphene				300							300
Alachlor											75
Atrazine											0 b/
Bromacil											69
2,4-D	1,200		164	60	219			50		280	3,065 b/
Diuron			160								160
MSMA			136	20							516
Sodium Chlorate			97								97
Trifluralin											0 b/
Captan											71
Creosote											0
Maneb											0
Pentachlorophenol											0
Tin Compounds											0
Para-dichlorobenzene											0
Methyl Bromide					0.25				0.185		0.435
Totals	5,090	0	1,129	638	235.25	235	1,700	63	1,463.185	496	27,857.435

---

a/ Relative proportion was not noted. It was therefore considered to be a 1:1 mixture.
b/ Received too late to be included in the totals:

Seattle, Washington	
Atrazine	26.3
2,4-D	4
Trifluralin	1.7

of simazine or TCA where less than 4 in. of asphalt is laid); and (c) general highway beautification (e.g., brush and broadleaf weed control along highways).

Although federal, state and local highways and roadways are treated, the state highway departments apply most of the herbicides. This is primarily due to the fact that state highway departments maintain both federal and state highways. Furthermore, more herbicide is used because these highways are wider and are treated more often than local roads. An estimated 1 million miles of state and federal highways are treated, and the right-of-way that is treated often amounts to 30 acres per mile on interstate highways. In contrast, the estimated 2 million miles of treated county highways have narrower rights-of-way and the estimated 1 million miles of treated township roads have even smaller rights-of-way, amounting to as little as 0.5 acre per mile.

The herbicide selected and the application rate will depend, of course, upon local conditions and control desired. Thus, substantial differences in herbicide use practice occur between different areas. The total estimated usage for the 18 major highway herbicides are given in Table XXVI.

Water management: Herbicides are used in the management of vegetative growth in water for several purposes, both in industrial-commercial sectors and in the governmental sector. Weeds or brush growing in irrigation canals may restrict the flow of water and increase losses by transpiration, those in drainage ditches may cause flooding, and those in streams and lakes may decrease recreational value or restrict navigation (e.g., in Louisiana, where much local traffic is by boat). An estimated 682,000 acres of waterways are treated with herbicides annually (including an estimated 60,000 miles of irrigation canals in the western U.S.), but the proportion of this that is in governmental sectors is uncertain. The estimated amounts of the 11 major herbicides that are used in this application are shown in Table XVII in Chapter V.

F. Summary of Governmental Pesticide Usage

Table XXVII gives a summary of governmental agency usage of the 25 intensive-study pesticides. The estimated total governmental use is a composite of reported federal usage within the continental states,* usage plus estimated total state and city usage.

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* For example, approximately 39,000 lb AI of malathion, listed as having "worldwide" usage were not included.

TABLE XXVI

ESTIMATED TOTAL HIGHWAY HERBICIDE USE[a]

Compound	Rate/Acre (lb)	Acres Treated (000)	Total Herbicide (million lb)
TCA	100	40	4.00
MSMA	1.5	2,220	3.33
Chlorate-borate	100	20	2.00
Ammate	100	20	2.00
2,4-D	1	1,800	1.80
2,4-D + 2,4,5-T	1	1,000	1.00
Dalapon	10	50	0.50
Simazine	4	120	0.48
Diuron	10	40	0.40
2,4,5-T	1	300	0.30
Atrazine	4	75	0.29
Aminotriazole	4	60	0.24
Prometone	4	50	0.20
Bromacil	4	50	0.20
Silvex	1	150	0.15
Tordon	6	20	0.12
Tandex	4	10	0.04
Paraquat	0.5	60	0.03
	Total	6,085	17.08

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a/ Source: Dr. Dale W. Young.

TABLE XXVII

DOMESTIC USE OF 25 INTENSIVE-STUDY PESTICIDES BY GOVERNMENTAL AGENCIES[a]

Pesticide[b]	Federal Agenices	State Agencies Reported in Survey	State Agencies Estimated Total	Municipal Agencies Reported in Survey	Municipal Agencies Estimated Total	Estimated Total Governmental Use (million lb)
Aldrin	907	4,565	6,253	0	--	0.008
Carbaryl	1,016,848	252,239	345,533	2,659	29,220	1.5
Carbofuran	281	1,000	1,370	0	--	0.002
Chlordane	328,107	22,498	30,819	932	10,242	0.5
Diazinon	767,377	10,303	14,114	2,000	21,978	0.8
Disulfoton	1,796	761	1,043	0	--	0.003
Malathion	695,085	980,488	1,343,134	17,913	196,846	2.2
Methyl parathion	6,063	421	577	0	--	0.007
Parathion	1,495	228	312	0	--	0.002
Toxaphene	30,084	3,299	4,519	300	3,297	0.04
Alachlor	883	3,114	4,266	75	824	0.006
Atrazine	58,707	88,415	121,116	0	--	0.3
Bromacil	36,327	113,678	155,723	69	758	0.3
2,4-D	1,708,824	320,610	439,192	3,065	33,681	3.0
Diuron	32,165	123,341	168,960	160	1,758	0.4
MSMA	37,677	191,768	262,696	516	5,670	1.0
Sodium chlorate	145,109	340,796	466,844	97	1,066	1.0
Trifluralin	894	6,804	9,321	0	--	0.01
Captan	7,355	7,810	10,699	71	780	0.02
Creosote	0	0	--	0	--	0.5
Maneb	21	1,858	2,545	0	--	0.003
PCP	< 1	298	408	0	--	0.001
Tin Compounds	--	0	--	0	--	0.00
Para-dichlorobenzene	6 gal.	607	832	0	--	2.0
Methyl bromide	43,053	112,082	153,537	< 1	5	0.2
Totals	4,899,058	2,586,983	3,543,813	27,857	306,125	13.8

---

a/ Source: MRI survey and Ref. 42.

b/ Data are in pounds except as noted.

The total pesticide figures for state usage were calculated from the reported pesticide usage by extrapolation on the basis of the relative populations of the reporting states (148,237,000) to the total U.S. population (203,185,000). Similarly, total municipal usage was calculated by extrapolation from the reported usage on the basis of the populations of reporting cities (13,537,000) and the total urban population in the U.S. (149,237,000). All population figures were from the 1972 World Almanac. The accuracy of this extrapolation method is uncertain, but it is as good as the reported data will allow. This method should also help take into account the nonmunicipal local government pesticide usage that was not directly covered in our survey. The sum of the estimated usage figures were, for a few pesticides, adjusted on the basis of other data to what we believe is a more accurate total. For example, para-dichlorobenzene's lavatory-space deodorant usages were probably not considered pesticidal, and consequently were not reported by city, state or most federal government agencies; the total given is supported by industry sources.

The total of 13.8 million pounds for use of the pesticides shown in Table XXVII by government agencies constitutes about 1% of the total domestic use of 24 of the pesticides, with creosote excluded.

In some instances, only very small amounts of the 25 intensive-study pesticides were reported, but substantial usage of other pesticides was noted. Texas, for example, reported usage of only one of the intensive-study pesticides and a total of only 10 lb AI. However, the Texas Highway Department alone used 4.5 million pounds TCA and 1.9 million pounds Ammate.® Therefore, quantities of "nonstudy" pesticides that had usages of 0.1 million pounds or more reported by federal, state and city government agencies are compiled in Table XXVIII. Note that these figures are "as reported" and are not extrapolated amounts as were those shown in Table XXVII.

TABLE XXVIII

QUANTITIES OF OTHER MAJOR PESTICIDES USED BY GOVERNMENT AGENCIES[a]

Pesticide	Million lb AI	Application[b]
TCA	5.39	H
Ammate® (AMS)	2.34	H
2,4,5-T	0.43	H
Naled (Dibrom®)	0.42	I,M
Flit MLO®	0.31	I
Dalapon	0.22	H
Simazine	0.22	H
Dichloropropene	0.21	Fu,N
Mirex	0.16	I
Zectran®	0.15	I
Copper Sulfate	0.15	F
Vorlex®	0.13	F,Fu,N
Amitrole	0.12	H
Monuron	0.12	H
Dylox® (trichlorfon)	0.11	I
Lamprecide® (TFN)	0.10	Lamprey killer

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a/ Includes usage within the continental U.S. reported to FWGPM by federal agencies (Ref. 42) and usage by state and city agencies reported by 35 states and 22 municipalities in response to an MRI survey.

b/ Application: F, fungicide; Fu, fumigant; H, herbicide; I, insecticide; M, miticide; N, nematocide.

VII. ENVIRONMENTAL IMPACT POTENTIAL OF PESTICIDES

A. Introduction

In this chapter, environmental properties, hazards and effects common to all pesticides,[43,44] and to certain categories of pesticides are discussed. These factors are not reiterated for individual pesticides in the Environmental Impact Potential sections of the Individual Case Studies in Chapter X of this report because otherwise, much repetitiveness would have resulted. Thus, the general discussions in this chapter and the environmental impact discussions for each product in Chapter IX complement one another.

Pesticides are potent, biologically active chemicals that are by nature toxic to one or more forms of life. Almost all pesticides are toxic not only to the target pest or pests, but also to nontarget organisms.

Most pesticides are released directly into the environment in the course of their intended use. According to estimates in Chapter III of this report, about 975 million pounds of pesticide active ingredients (not including sulfur, creosote, petroleum and p-dichlorobenzene) were applied for all purposes in the United States in 1972. If this quantity were blanketed uniformly over the entire U.S. land area (2.3 billion acres), the rate of deposit would be 0.42 lb of active ingredient on each acre of land. Since only a small percentage of the total U.S. land area receives pesticide treatments, treated areas receive much higher deposits of pesticides each year. (Further details on agricultural applications of pesticides are discussed in Chapter IV of this report.)

B. Mammalian Toxicity

Many pesticides are toxic to man and higher animals. Toxicity may result from direct exposure by inhalation through the respiratory tract; by ingestion through the gastrointestinal tract; and/or through the skin by contact with the pesticide itself or with its residues. Some pesticides cause irritation to the skin, the eyes and/or the respiratory tract, or allergic skin reactions. Toxicity may also result from ingestion of toxic residues in (or on) food or feed.

The acute and chronic toxicity of many pesticides to mammals, especially to small laboratory mammals, their metabolism in mammals, and their persistence in treated crops, meat animals, and animal products have been studied extensively. Data on these properties of pesticides are required for pesticide registration and for the establishment of residue tolerances in raw agricultural commodities, food, or feed. During the last few years, concern has also developed for possible health hazards to pesticide operators and workers, including pesticide applicators and their helpers, field workers such as fruit pickers, insect scouts, flagmen, etc.

Mammalian toxicity of pesticides is discussed in this chapter, and in the individual case studies, as one of several indicators of the environmental impact potential of pesticides. While data from toxicity studies on laboratory mammals are not directly applicable to field conditions, they give an indication of the general order of toxicity of the pesticide, and of possible hazards to wild mammals.

Data on the acute toxicity to laboratory animals, primarily rats, are available for all commercial pesticides. However, data on the same chemical from different sources often vary considerably, especially in the case of less toxic compounds. This is not surprising because many variables affect the outcome of such toxicity tests, e.g., the species, strain, age, sex and general condition of the experimental animals used; whether or not the animals were fasted prior to administration of the toxicant; the time of day when the toxicant was given; the form in which the active ingredient was administered (e.g., formulated, technical or highly purified; type of formulation; the other formulation ingredients; physical state; particle size, etc.), the mode of administration, and others. These factors can cause large variations in results, especially in the case of chemicals that are poorly absorbed from the gastrointestinal tract, the respiratory tract, or the skin. With such pesticides, vast differences in LD_{50}'s are seen when the chemical is applied in a suitable solvent in solution, as compared to application in a solid form, especially if the solid form is a low-concentrate granular or dust formulation.

For these reasons, direct comparisons between LD_{50} data obtained in different tests by different investigators are often misleading. For purposes of the present study, we feel that comparisons by toxicity categories are more useful and have, therefore, preferred this approach in this chapter as well as in the individual product profiles. Table XXIX presents a summary of the acute toxicity criteria by which pesticides are assigned to four commonly used categories of toxicity.

Data on the toxicity of pesticides to wild mammals, fishes, and to lower terrestrial or aquatic organisms are incomplete for many products, and almost totally lacking for many others, especially older products. Those data that are available in this field often were obtained under such diverse experimental or field conditions that direct numerical comparisons are not meaningful. In discussing widldlife toxicity, we have again preferred categories, rather than individual or numerical observations, following largely the definitions suggested by von Rümker and Horay,[45] summarized in Table XXX.

TABLE XXIX

MAMMALIAN TOXICITY CATEGORIES OF PESTICIDES[45]

Toxicity Parameter/Category	Highly Toxic	Moderately Toxic	Slightly Toxic	Relatively Nontoxic
Acute oral LD_{50}, mg/kg	Less than 50	Over 50-500	Over 500-5,000	Over 5,000
Acute dermal LD_{50}, mg/kg	Less than 200	Over 200-2,000	Over 2,000-20,000	Over 20,000
Acute inhalation LD_{50}, μg/liter	Less than 2,000	Over 2,000-20,000		
Dose probably lethal to a 150 lb man	A few drops to 1 teaspoonful	1 teaspoonful to 1 oz	Over 1 oz to 1 pt or 1 lb	Over 1 pt or 1 lb
Signal word required on label	Danger - Poison Skull and Crossbones	Warning	Caution	

TABLE XXX

WILDLIFE TOXICITY CATEGORIES OF PESTICIDES

"Highly Toxic"

Severe losses may occur if the pesticide is used in or over a habitat containing the animals or organisms specified. "Use" of the pesticide in this context means use at recommended dosage levels, including such overuse as may be expected in normal operations from overlapping swaths, inadvertant double treatment, miscalibration, etc.

"Moderately Toxic"

Moderate losses of the animals or organisms specified may occur under the operating conditions outlined in the preceding paragraph.

"Slightly Toxic"

Slight losses or injury to nontarget organisms may occur.

"Relatively Nontoxic"

No losses or injury to nontarget species are likely to occur, allowing for a considerable margin of overuse, misapplication, miscalibration, or other ordinary operation mishaps.

C. Toxicity to Other Nontarget Organisms

Pesticides may also affect lower terrestrial or aquatic organisms, including organisms that are important to vital natural biological waste degradation and/or oxygen production mechanisms. However, harmful effects to such organisms will probably not be as obvious or dramatic as, for instance, kills of fish, birds or wild mammals, and may, therefore, go unnoticed unless and until they result in more apparent consequences.

Persistent pesticides and/or their metabolites and degradation products may accumulate in the environment, especially in or near treated areas. Accumulation will occur in local soils or waters when the rate of pesticide input into the area exceeds the rate of degradation and/or transport out of the area.

Pesticides may accumulate in biological organisms because of the ability of animals and plants to concentrate many types of pesticides in their body tissues. If this process is repeated through several links in a food chain, very high concentrations of pesticide residues can occur in species at the top of the chain. This phenomenon has been studied and documented most comprehensively in the case of DDT.

Even the most selective and specific pesticides will affect the ecosystem in the target area. If only the target pest(s) are decimated, neighboring organisms in the system will also be affected such as, for instance, organisms that depend upon the target species for food or shelter. Often, pesticides directly affect not only the target pest(s), but many nontarget species as well. Effects on nontarget species often extend beyond target areas, because pesticides and their metabolites and/or degradation products move away from the site of deposit by drift, volatilization, leaching, and/or surface transport in water or on sediment. The degree to which pesticides move throughout the environment by these processes is related primarily to their chemical stabilities, their solubility characteristics, and their absorption on soil particles.

In recent years, many expert committees, panels, conferences, symposia and individual investigators have dealt with the human and environmental health effects of pesticides and their fate in the environment after application. Two reviews are of special interest. A very comprehensive review was undertaken in 1969 by a commission of distinguished scientists under the chairmanship of E. Mrak.[43] This group, supported by a competent professional staff and several advisory panels, drew on the advice and cooperation of many additional scientists and other knowledgable persons. Nevertheless, the commission's final report to the Secretary of Health, Education, and Welfare contains vastly more information on the effects of pesticides and pesticide residues on humans and on laboratory animals than on other nontarget organisms; this difference reflects the relative availability of information in these areas. The second study, commissioned by the Office of Science and Technology, Executive Office of the President, thoroughly reviewed the ecological effects of pesticides on nontarget species and recorded the data that were found.[46]

These two comprehensive surveys indicate that relatively little information is available on the toxicity and hazards of pesticides and their residues to nontarget organisms under field conditions. Information is especially sparse concerning the effects, if any, of pesticide residues on lower aquatic and terrestrial organisms. There is a copious literature on the effects of individual pesticides on isolated organisms or systems in the laboratory or greenhouse over short periods of time. However, such studies are usually far removed from field conditions, and their results do not answer the question of their significance in regard to field conditions. Even less information is available on the combined effects of residues of two or more pesticides on nontarget organisms.

Following the discovery of the adverse effects of DDT on animals at the tops of food chains, the attention of many researchers turned to the phenomena of bioaccumulation and biomagnification that could produce these types of effects. Pesticide monitoring studies have centered on chlorinated hydrocarbon insecticides. The possibility that pesticides may affect terrestrial or aquatic ecosystems in other ways has received less attention. By virtue of their physical, chemical and biological properties, fungicides and herbicides are more likely to affect the lower trophic levels of food chains. It is not known whether or not currently practiced monitoring and observation methods would detect such effects prior to the occurrence of massive ecological damage.

D. Pesticide Residues in the Environment

Most studies on pesticide residues, metabolism and degradation conducted thus far have been focused on crops and/or livestock and on laboratory mammals, in support of registration and tolerance petitions. By contrast, much less is known about the metabolism and degradation of pesticides in other elements of the environment, and on the chemical pathways, rates and other factors involved. This lack of information on the environmental degradation of pesticides msut be considered in the interpretation of pesticide monitoring data, soil persistence studies, etc. In most instances, only the presence or absence of the parent compound is reported, and the data do not include metabolites or degradation products. In most persistence studies involving sequential sampling, it remains unclear whether the pesticide truly "disappeared" by way of degradation to harmless breakdown products, whether it was transformed to one or more other biologically active chemicals beyond the scope of the analytical method(s) employed, and/or whether it moved away from the sampling site unchanged by atmospheric, surface or subsurface transport mechanisms.[47]

1. Soil residues: Comprehensive data on soil residues of pesticides have been presented.[48] These authors reported on pesticide residue levels in soils found in fiscal year 1969 in the National Soils Monitoring Program for Pesticides. Geographically, the report covers cropland soils in 43 states, and noncropland soils in 11 states. Five large agricultural states (Oregon, Montana, Minnesota, Kansas, and Texas) were not included in the program.

A total of 1,729 samples of cropland soil were collected. All samples were analyzed for residues of arsenic, 12 chlorinated hydrocarbon insecticides and some of their metabolites, the herbicides DCPA (Dacthal) and trifluralin (Treflan), the fungicide PCNB, and the cotton defoliant Def. Soil samples were analyzed for the herbicides atrazine and 2,4-D, and for five organophosphate insecticides (carbophenothion, diazinon, ethion, malathion, and ethyl parathion) only when use records indicated that these pesticides had been applied at a given sampling site. In this manner, 199 samples were analyzed for residues of atrazine, 188 for 2,4-D, and 66 for the organophosphate insecticides.

This survey is thus heavily weighted in favor of chlorinated hydrocarbon insecticides. It includes several minor pesticides and omits a number of widely used products.

Arsenic residues were found in 99.3% of the cropland samples, most or all of them probably resulting from natural sources of arsenic.

The next most frequently found residues were those of dieldrin and aldrin; they were present in 27.8% and 10.9% of all cropland samples, respectively. Residues of DDT and/or its metabolites were found in 26.1%, and chlordane residues in 8.7% of the cropland samples.

The highest DDT residues were found in the states of Alabama, California, Michigan, Mississippi and South Carolina. In all of these states except Alabama, the amounts of DDT reportedly applied to the sample fields were lower than the mean DDT residue levels found. In all five states, the percent of sampling sites positive for DDT residues was three to four times greater than the percent of sites reportedly treated with DDT.

The same pattern prevailed in regard to dieldrin residues. In the seven states in which the highest dieldrin residues were found, i.e., Florida, Illinois, Iowa, Kentucky, North Carolina, Virginia, and West

Virginia, the number of sites reportedly treated with aldrin or dieldrin was consistently lower than the number of sites at which aldrin/dieldrin residues were found. In most cases, the average amount of aldrin/dieldrin applied was very close to the mean residue of dieldrin detected in the soil.

These findings indicate that there is substanital carry-over of residues of these persistent pesticides from one season to the next or beyond, and migration of residues from treated fields to other areas through environmental transport mechanisms.

2. Residues in the aquatic environment: Pesticides may enter into aquatic systems through point or nonpoint sources. Potential point sources include industrial operations such as production and formulation of pesticides, reclamation of used pesticide containers, use of pesticides for protection or preservation of wood, fabrics, paint, paper, stored products, etc. Pesticide-containing effluents from such operations may be primary point sources, or may be discharged into wastewater collecting systems whose effluents then become point sources of pesticide pollution, unless wastewater treatment steps in the system decompose the pesticide residues. Additional pesticide residues may be contributed to such systems through the use of pesticides within urban or suburban areas served by the system, willful dumping of unwanted pesticides, etc. Sometimes, pesticides are applied directly to bodies of water, for instance, for control of mosquito larvae, control of aquatic weeds, etc.

Nonpoint source pollution of aquatic systems by pesticide residues arises from the use of pesticides in agriculture, forestry, in public health programs, and generally in areas not served by wastewater collecting systems. In most instances, pesticide residues are initially deposited in or on soil. Soil pesticide residues may become water pollutants by way of several transport mechanisms.

They may be dissolved or emulsified in water leaching or running off from land containing residues, or adsorbed on inorganic or organic solids carried into waterways by erosion.

Pesticide residues may also become airborne, either directly by volatilization, codistillation or sublimation, or passively by wind erosion. Through precipitation, such airborne pesticide residues may be deposited on water surfaces. In view of the distribution of land and water on our planet, atmospheric cycling of pesticide residues may carry substantial quantities of these substances to the oceans, while pesticide residues in inland waters probably come primarily from overland transport. Such movement of pesticide residues from soil into waterways is a complex process, subject to a multitude of factors including the physical and chemical properties of the pesticide, the formulation, the rate and type of application, the target crop, tillage practices, topography of the field, topography of the area between the field and waterways, distances involved, weather conditions, especially amount and velocity of rainfall soon after application of the pesticide, and many others. No data are available on the relationships between quantities of pesticide input and pesticide residues in rivers, lakes and oceans.

In considering possible effects of pesticide residues in water on aquatic ecosystems and water quality, it must be recognized that such residues do not enter into, or travel in waterways at constant rates, but in uneven slugs. The largest slugs, often probably consisting of multiple pesticide residues, are likely to occur in the spring when the heaviest use of pesticides in agriculture coincides with intensive precipitation. Pesticide concentrations will vary greatly at different times and places along waterways and may fluctuate from harmless to injurious levels at any given point. If and where concentrations harmful to one or more aquatic organisms occur, their aftereffects are likely to be more prolonged than the residence time of the harmful amount of toxicant(s) itself.

Pesticide residues in major river systems are eventually discharged into estuaries, areas that marine biologists consider to be among the world's most ecologically sensitive areas.

Several federal and state water monitoring programs include pesticides. Analytical data from these sources are stored in Storet, a data storage and retrieval system maintained by the Environmental Protection Agency that is intended to be the depository for data of this type from all federal programs. Nonfederal inputs to Storet, such as data from state programs or private sources, are voluntary and are often not made because of lack of resources. In a recent EPA-funded study on "Pesticide Use on the Nonirrigated Croplands of the Midwest"4/ an analysis was made of all available STORET data on pesticides for selected stations along the mainstreams of the Mississippi, Missouri and Kansas rivers. The great majority of the samples were negative for the pesticides analyzed which included aldrin, dieldrin, endrin, BHC, chlordane, DDT and two of its metabolites, heptachlor and its epoxide, malathion, ethyl and methyl parathion, diazinon, 2,4-D, 2,4,5-T, and silvex. However, many samples were taken at times when residues of these pesticides would be unlikely to be present. Almost no values were reported for pesticide residues on suspended solids or sediment.

In view of the highly seasonal uses of most pesticides, data on pesticide residues obtained from analysis of samples taken for other purposes, on sampling schedules and at sampling stations not geared to pesticide use patterns, are not likely to answer questions concerning what effects, if any, waterborne pesticide residues have on aquatic ecosystems and water quality.

The current state of knowledge of the fate of organic pesticides in the aquatic environment was reviewed at a symposium sponsored by the American Chemical Society in 1971.[49] In a keynote presentation at the conference, Johnson and Ball[50] summarized the situation as follows: "Our lack of knowledge regarding the fate of chemicals in major aquatic ecosystems has resulted in confusion and poorly defined issues regarding the hazards of chemical contaminants to human health and loss of environmental quality."

3. Residues in air: While data on soil and water residues of pesticides are far from abundant, even less is known about their presence and movements in air. Pimentel[46] summarized the few data available. Almost all of these pertain to chlorinated hydrocarbon insecticides, predominantly DDT and its derivatives.

These data indicate that pesticide residues in air are quite ubiquitous. It appears that pesticides in the air as a result of drift may remain airborne for prolonged periods of time. Volatilization, sublimation, codistillation and wind erosion apparently propel additional quantities of pesticides into the atmosphere. Airborne pesticide residues from these sources appear to travel great distances, and this transport mechanism is probably responsible for the reported presence of pesticide residues in arctic and antarctic wildlife, and in many other places far removed from areas of use.

E. Environmental Impact Potential of Pesticides by Categories

1. Insecticides: Insecticides affect insects by contact, stomach and/or inhalation action. Contact poisoning may result if a dry or liquid insecticide particle impinges directly on an insect, or if an insect contacts a residual deposit of the insecticide. So-called "systemic" insecticides penetrate into treated plants through roots and/or foliage and are translocated inside the plant, killing sucking insects that suck toxic plant juices, and/or chewing insects feeding on toxic plant tissues.

Insecticides may be applied to the soil, to plant foliage, as a space treatment against flying insects, as a residual treatment to inert surfaces, stored products, etc., or to water. Most soil treatments are preventive in nature, i.e., the insecticide is applied before infestation levels of the target pest(s) can be determined. Foliar insecticides are sometimes applied on preventive, preprogrammed, so-called "wash day" schedules. However, in most instances, "curative" use of foliar insecticides (only if and when needed) is possible. Preventive use of insecticides is especially attractive from an economic standpoint if target pest(s) are believed to occur regularly, and if an inexpensive insecticide is available. In such instances, the insecticide use is essentially an insurance measure that protects the grower against a potential loss. In addition, it relieves him of the need to worry whether or not a treatment may actually be required, whether the weather will be favorable, whether labor and equipment will be available when a treatment may be needed, etc. Preventive use of soil insecticides is encouraged by the fact that for most soil insects, no simple and reliable diagnostic methods are available.

Most pesticides classified as "highly toxic" to mammals are insecticides. For this and other reasons, the toxicity and hazards of insecticides and their residues to human health and to nontarget organisms such as wild mammals, birds and fishes have been studied more extensively than those of herbicides, fungicides, and other pesticides.

Cumulatively to date, insecticides have been used in larger quantities worldwide than herbicides, fungicides or other pesticides. However, in the U.S., herbicide surpassed insecticides in volume of annual use several years ago. (The world use of herbicides continues to grow at a more rapid rate than that of insecticides.)

Insecticides affect the quality of ecosystems primarily by their effects on other animal species. Even if a given insecticide would destroy only the target insect pest, other animals depending upon that species for food would be indirectly effected. In most instances, an insecticide application affects not only the target pest(s), but also nontarget species. The latter may include species beneficial to man such as honeybees, or parasites or predators that would limit population levels of harmful insects if left undisturbed. Elimination of such predators or parasites may bring about increasingly rapid resurgence of the target pests following treatments.

In other instances, pests of minor economic significance may build up to damaging proportions if other insects against which they were in competition are removed from the system.

Furthermore, many insects have developed resistance to insecticides, often to the point where insecticides that were at first highly effective have become completely useless. In situations where development of resistance in the target insects and destruction of their natural enemies coincide, chemical insecticides ultimately fail completely from an economic as well as from a biological standpoint. In this unhappy chain of events, the net benefits from the use of chemical insecticides diminish steadily, while both the monetary and ecological cost of control increase to the point where they become unacceptable.

Insecticides and their residues may also affect nontarget organisms other than mammals, birds, fishes and arthropods, but much less information is available on hazards to such other organisms.

a. Chlorinated hydrocarbon insecticides: In spite of numerous studies in many countries, the mechanism of action of chlorinated hydrocarbon insecticides (including DDT) is not understood to this date. No specific antidotes are available for treatment of cases of human poisoning by chlroinated hydrocarbon insecticides.

This group includes several pesticides whose residues are very persistent, including DDT and aldrin/dieldrin. Monitoring data indicate that in areas of heavy use of these persistent pesticides, application rates have exceeded rates of degradation, resulting in accumulation of residues in the environment. Through atmospheric and surface transport mechanism, residues of these persistent insecticides have been widely distributed over our entire planet.

b. Organic phosphate and carbamate insecticides: These insecticides have several important characteristics in common. Their biochemical action is based on the inhibition of cholinesterase, a vital body enzyme present in many species throughout the animal kingdom. A large percentage of the pesticides in the "highly toxic" category of mammalian toxicity are organic phosphate or carbamate insecticides, including such highly poisonous chemicals as aldicarb, TEPP, parathion, and others. Fortunately, effective antidotes are available for the treatment of organic phosphate and carbamate poisoning. These antidotes reactivate the inhibited cholinesterase enzyme (pralidoxime chloride), or counteract the effects of enzyme inhibition (atropine sulfate) within the organism. They are thus highly specific, and often dramatically effective in cases of human poisoning. However, since their action is curative in nature, they do not offer promise for the prevention of poisoning in humans or other nontarget species.

2. Herbicides: Herbicides are used in the following ways:

- Preplanting, that is before seeding or planting of the target crop.

- Preemergence, that is at the time of seeding of the crop, or up to the time just prior to crop emergence. At this stage, contact herbicides will destroy emerged susceptible weeds before emergence of the crop seedlings; residual herbicides will destroy susceptible weed seeds and germinating seedlings.

- Postemergence, that is after emergence of the target crop.

Preplant and preemergence herbicide uses are inherently preventive in nature. However, previous history of a given field usually indicates to the grower the extent of weed problems he is likely to experience.

The majority of present-day herbicides in the U.S. are applied to the soil preplant or preemergence, by ground equipment. This mode of application considerably reduces or eliminates the problems of drift and pesticide deposits outside of the target area. These problems are common if pesticides are applied several or many feet above ground, as in the case of application by air or high-clearance ground equipment.

Herbicides affect ecosystems in the target area by the elimination of susceptible plant species. Thus they change the habitat of other plants and, more importantly, the habitat of animals in the area. Herbicides may also affect lower terrestrial or aquatic organisms, although systematic field observations in this regard are almost nonexistent. To the extent that biologically active herbicide residues are transported beyond target areas, these effects would be spread.

Development of resistance to herbicides in target weeds has been reported in some instances, but to this date, resistance has not become a major problem. However, continued use of herbicides in certain areas has resulted in the gradual elimination of easy-to-kill vegetation, and the spread of species that are more difficult to kill, especially deep-rooted perennial plants.

Use of herbicides for the control of aquatic weeds entails the same problems in principle, but effects on nontarget organisms may appear more quickly, be more profound, and extend more readily to areas further removed from the site of application of the herbicide because the water medium represents a more active transport system than the soil/plant/air system. Only a very small percentage, probably less than 1%, of all herbicides used in the United States are applied to aquatic systems directly for the control of aquatic weeds.

Most herbicides are only slightly toxic or relatively nontoxic to mammals. Most studies on the metabolism and degradation of herbicides focus on one or more of the following areas: (a) herbicide residues in treated crops (with a view to the establishment of residue tolerances, or exemptions from the need for same), (b) the possible effects of herbicide residues in the soil on crops following in the rotation, or (c) the effects of these residues on other desirable vegetation. By contrast, very little information is available on the degradation of herbicide residues in other elements of the environment, or on the effects of herbicides on other nontarget organisms.

Chemically, herbicides represent a considerable variety of chemical families. They vary widely in their mechanism of action. For many herbicides, considerable information is available on how they affect plants, but much less is known on the mode of toxic action on mammals. However, in view of their generally low mammalian toxicity, the latter has not been considered a pressing problem.

3. Fungicides: From the biological standpoint, control of plant pathogens by chemical fungicides is a difficult problem because both the pathogen to be destroyed and the crop to be protected belong to the plant kingdom. Besides, they usually live in such close physical and biochemical association that the crop is often rightfully referred to as the host. By contrast, insecticides are employed in crop protection to control animals on plants. In the case of weed control, the "pest" is usually at least physically separated from the crop, rather than living on or in it, although both are plants.

Thus, in the development of fungicides, achievement of an adequate safety margin between toxicity to the host and toxicity to the pathogen is a difficult task. In crop protection, most fungicides are applied to the foliage of plants to be protected from fungal pathogens. Much smaller quantities of fungicides are used for the treatment of seeds, to protect them and the germinating seedlings from soil- or seed-borne pathogenic fungi.

Most fungicides are not capable of destroying plant-pathogenic fungi after they have become established on the host plant. Therefore, they have to be applied protectively, i.e., before attack of the fungus. Only a few fungicides act curatively, i.e., are capable of destroying fungi that have already invaded the host plant, but have not yet generated spores that will initiate a new generation of the fungus. Even fewer fungicides are true eradicants, i.e., capable of eradicating an infection of the pest fungus after sporulation has already taken place.

Most fungicides (with the exception of heavy-metal derivatives) are only slightly toxic or relatively nontoxic to mammals. Most of the fungicides currently in widespread commercial use were developed many years ago, prior to the time when data on environmental behavior and toxicity became registration requirements. As a result, relatively little information is available today on the possible toxicity of fungicides to nontarget organisms, and on their metabolism, degradation and fate in the environment. Only one fungicide, PCNB, was included in the National Soils Monitoring Program.[48]

By virtue of their biological and chemical properties, fungicides are most likely to affect lower terrestrial and aquatic nontarget organisms.

In most fungicide applications, thorough coverage of the plant to be protected is essential. Consequently, fungicides are usually applied by ground equipment which reduces the drift hazard. Many fungicides are rather instable on plant foliage, and their residual effectiveness declines rapidly. In many instances, multiple applications at short intervals are required when conditions for establishment of infections by the pathogen are present.

Inorganic and organometallic fungicides are generally more persistent than nonmetallic organic chemicals. Organic mercurial fungicides resemble persistent chlorinated hydrocarbon insecticides in some of their persistence characteristics. However, use of mercurial chemicals as fungicides represents only a small fraction of the total use of mercury in the U.S. Nevertheless, most registrations of mercurial fungicides were cancelled some time ago, and their use for this purpose has almost ceased at this time.

As discussed in greater detail in the chapter on alternatives (Chapter IX), very few nonchemical methods are available for the control of fungus diseases on plants.

Fungicides are produced and used in the U.S. in much smaller quantities than insecticides and herbicides.

Based on past history, the greatest hazard from the use of fungicides appears to be misuse of seed treated with fungicides toxic to mammals. In the U.S. as well as in other countries, misuse of treated seed for direct human consumption or as animal feed has resulted in poisoning epidemics, some resulting in fatalities.

VIII. WASTEFUL PESTICIDE USE PRACTICES

A. Introduction

There are several major potential sources of waste associated with the use of pesticides, including pesticide losses during application, misuse, overuse, and unnecessary use. Very few efforts have been made to quantify such wasteful use practices. Even the matter of definition presents a problem. For instance, a grower using a pre-emergence, soil-applied herbicide or insecticide on a preventive basis, i.e., before the target pests actually appear, considers this pesticide use a protection against possible yield losses and thus a necessary investment, especially in cases where curative pest control methods are not available, not as effective, not as convenient to apply, and/or more expensive than the preventive treatment. From a biological and ecological standpoint, the preventive treatment might be considered wasteful if and to the extent that pest infestations fail to materialize.

As mentioned above, very few, if any, studies have been conducted thus far in which wasteful pesticide use practices have been systematically investigated, quantified and documented. No universally accepted definitions have been established delineating wasteful from nonwasteful pesticide uses. The great divergence of opinions on this point is illustrated, for instance, in the present legal proceedings in connection with the cancellation of the registration of the insecticide aldrin. Expert witnesses have presented widely divergent views in court on whether the use of aldrin as a soil insecticide is essential or wasteful.

In the absence of established criteria and well documented studies on wasteful pesticide use practices by products and crops or other uses, it has not been possible to identify specific "wasteful" uses in the case studies in this project. However, several actual and potential sources of waste are common to the use of all pesticides. These are discussed in the following sections of this chapter.

B. Application Losses

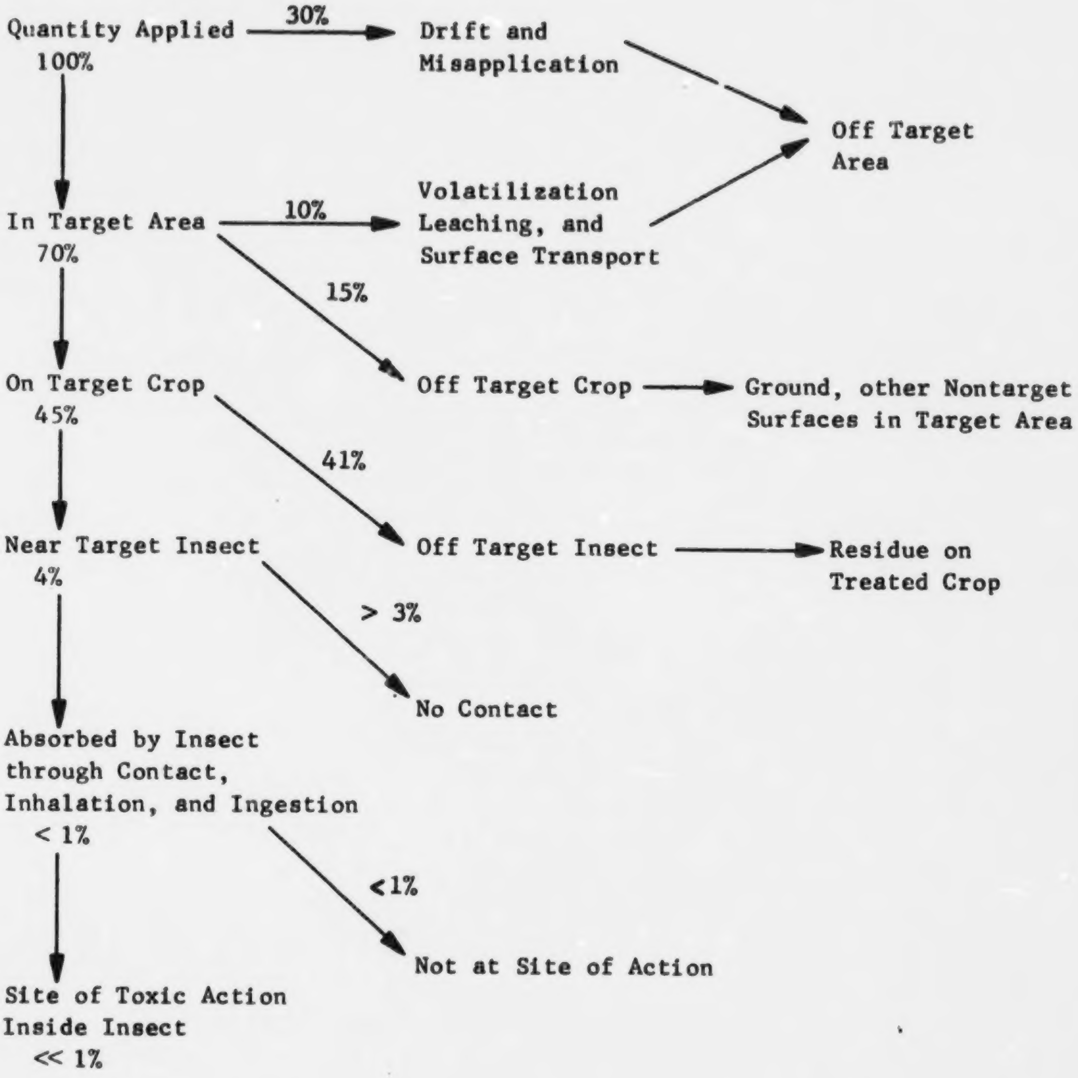
Chemical pesticides have been widely accepted and are today the principal tool for the control of pests in agriculture, industry and public health. One important reason for their large-scale use is their favorable cost/effectiveness ratio. Many pesticides provide a high degree of pest control per dollar spent and, in many instances, are the most economical, efficient and convenient means of pest control. This is especially true if possible consequences of unwise use of pesticides over extended periods of time are disregarded.

However, most pesticide uses are highly inefficient from an ecological standpoint, considering the quantity/effectiveness ratio. Figure 6 presents a schematic description of the fate of a given quantity of insecticide sprayed topically on a crop. The percentage loss figures (in terms of the quantity applied = 100%) do not represent one specific case, but are composited from several different field studies. Typical losses due to drift were taken from the studies by Adair et al.,[51] Akesson and Yates,[52] and Brazzel et al.[53] Losses due to surface runoff from the target area were composited from the studies by Caro et al.,[54] Ritter et al.[55] and White et al.[56] Information on the propensity of pesticides for volatilization and leaching has been reported by von Rümker and Horay.[45] It has further been assumed that the degree of ground cover of the target crop in the target area is 75%, and that not more than 10% of the insecticide quantity impacting on the target crop will impact near a target insect. Of that quantity (4% of the applied rate), only a small portion will actually be absorbed by target insects through contact, inhalation and/or ingestion so that ultimately, only a very tiny fraction of the quantity applied (much less than 1%) will reach the site of action inside the target insect.

Under field conditions, the rates of pesticide loss at each step may vary greatly depending upon all elements in the system and their interrelationships, including type and velocity of application equipment, pesticide formulation, particle size, atmospheric and weather conditions, degree of ground cover of the crop, density of target pests on the crops, and other factors. However, regardless of how these factors interact, only a very small fraction of the pesticide quantity applied actually becomes effective for the intended purpose, the destruction of the target pest. In many agricultural pesticide applications, more than 99% of the applied dose never reaches the ultimate target, but becomes an unwanted residue on the treated crop and in the environment inside or outside of the target area. Shaw and Jansen[57] presented a similar mass balance for herbicide uses. Mass balances for other types of farm pesticide uses, such as fungicides or soil insecticides, may be somewhat different, but in most instances, they too are very inefficient if evaluated by the quantity/effectiveness ratio.

Thus, large quantities of chemical pesticides could be saved and unwanted residues on treated crops and in the environment could be reduced, without sacrificing any benefits, if the chemical's route from the application equipment to the site of action inside the target pest could be made less wasteful. Opportunities in this regard include reduction of drift, improvement of placement within the target area, attracting target pests to pesticide deposits in order to increase the effective radius of each deposit and to reduce the total number of deposits required, etc.

In the light of the magnitude of this problem, it is surprising that very little, if any, systematic research attention has been devoted to this area thus far.


Quantity Applied
100%
30%
Drift and
Misapplication
Off Target
Area
Volatilization
Leaching, and
Surface Transport
In Target Area
70%
10%
15%
On Target Crop
45%
Off Target Crop
Ground, other Nontarget
Surfaces in Target Area
41%
Near Target Insect
4%
Off Target Insect
Residue on
Treated Crop
> 3%
No Contact
Absorbed by Insect
through Contact,
Inhalation, and Ingestion
< 1%
<1%
Not at Site of Action
Site of Toxic Action
Inside Insect
<< 1%

Percentage distribution figures do not represent one specific case, but are composited from several different field studies and assumptions on the degree of ground cover, and the density of target insects on the target crop (see text).

Figure 6 - Foliar Insecticide Application: Typical Losses
Between Spray Nozzle and Site of Toxic Action

C. Overuse

When chemical pesticides first came into widespread use after World War II, they initially provided spectacular and unprecedented control of insects, weeds, and other pests. Pesticide developers, marketers and users soon became used to nearly 100% control of pests, and this became the standard for the development and registration of pesticides, and for application rates recommended by producers, federal and state extension services, and others.

However, fairly soon, undesirable results became increasingly apparent, including the development of pest populations resistant to pesticides; rapid resurgence of target pest populations following treatment; outbreaks of secondary pests which did not cause economic damage previously; undesirable residue levels on food crops and in many other elements of the environment, including man himself; and adverse effects on wildlife.

It was also realized that in many instances, close to 100% control of target pests is not necessary for prevention of yield losses and that, in fact, lower rates of application may be more advantageous because they allow greater survival of beneficial predators and parasites which assist in the suppression of pest insects and thus often help to reduce the need for more pesticide applications.

An interesting example of these interrelationships has been presented by Cate et al.[58/] in a study on the management of the greenbug, Schizaphis graminum, on grain sorghum. The standard application rate of parathion emulsifiable concentrate for the control of this insect is 0.5 lb AI/acre. This rate provided 98% seasonal control of the greenbug, and a sorghum seed yield of 4,400 lb/acre. At the rate of 0.1 lb AI/acre, parathion provided 94% seasonal greenbug control, and a sorghum seed yield of 4,450 lb/acre.

In the same test, the standard recommended rate of disulfoton granular, 1.0 lb AI/acre, provided 99% seasonal control of greenbugs, and a sorghum seed yield of 4,333 lb/acre. At 0.1 lb AI/acre, disulfoton granular provided 80% seasonal control of greenbugs, and 4,033 lb/acre of sorghum seed.

For both products, the degree of seasonal greenbug control and the sorghum seed yields achieved at the different rates of application were not statistically different at the 5% level.

These data indicate that economic control of greenbugs on sorghum can be obtained at application rates substantially lower than the standard recommended rates which appear on the registered labels of these insecticides. Similar results have been reported at recent meetings by entomologists working on other crop/pest combinations, especially on field and forage crops where insects affect primarily the quantity rather than the quality of crop yield. By contrast, certain fruit and vegetable crops, especially those intended for the fresh market, have a much narrower insect damage tolerance margin.

Thus, there are indications that at least on some major crops, currently registered "standard" rates of insecticides may be unnecessarily high. However, a question has recently arisen whether or not in the future, pesticides can be recommended and used at such reduced rates of application if these rates are lower than those specified on the registered product label. Section 12, "Unlawful Acts," (A) (2) (G) of the 1972 amendments to the Federal Insecticide, Fungicide and Rodenticide Act, Public Law 92-516, states, "It shall be unlawful for any person to use any registered pesticide in a manner inconsistent with its labeling." It is possible that this clause of the new pesticide law will result in the recommendation and use of pesticides at rates of application higher than economically necessary or ecologically desirable.

D. Unnecessary Use

The question whether or not a given pesticide application is unnecessary and thus wasteful is often difficult to decide. First of all, a certain pesticide use might be biologically or ecologically wasteful, but might still be economically profitable, at least in the opinion of the pesticide user. Oftentimes, there is no way for the user to determine with certainty whether or not the use was actually profitable, but the opinion that it was profitable in the past, and the expectation that it will continue to be profitable in the future provide sufficient incentive to continue the practice.

All preventive and preprogrammed pesticide applications are potentially wasteful. Included in this category are, for instance, pre-emergence applications of insecticides, herbicides, or fungicides; and all other pesticide uses in which the product is applied prior to the actual presence of the pest in damaging numbers. However, some pesticides are effective only when applied preventively; they are unable to eliminate or eradicate pest or disease infestations once established. Many fungicides fall in this category, including captan (Case Study No. 19) and maneb (Case Study No. 21).

Many herbicides, including alachlor (Case Study No. 11) and trifluralin (Case Study No. 18), work against weeds only in the germination or early seedling stage, before they emerge. Many other herbicides, while effective against emerged weeds in varying degrees, usually work better if applied prior to weed emergence and therefore are primarily used on a preventive, rather than a curative basis.

The preventive use of fungicides and herbicides is usually justified on the basis of prior experience which indicates to the grower if, when and where weed or disease infestations are likely to occur. Good methods for the prediction of plant disease occurrence have been developed for many crop disease systems. In the case of weeds, experienced growers who know their fields are usually able to anticipate weed problems, although the degree of weed pressure may be greatly influenced by the weather, which is largely unpredictable.

The situation is more difficult in regard to the use of insecticides, especially soil insecticides that have to be applied preventively. For instance, if a grower uses aldrin as a preventive treatment against corn soil insects at a cost of $2 to $4/acre, he does not consider this wasteful, even though he may know that only a small percentage or none of the area treated might be invaded by soil insects. If the actual infestation level turns out to be 10%, then 90% of the aldrin quantity applied might be considered a "wasteful use." However, the problem is that no one at the present state of the art is able to predict which portion of a given field might or might not be damaged by soil insects, and many corn growers consider the postemergence "curative" treatments recommended against corn soil insects to be inconvenient and unreliable.

A somewhat similar situation exists on crops such as cotton in areas where the crop is known to be subject to insect infestations regularly, year after year. In these areas, many growers have adopted preprogrammed, or so-called "wash-day" type insecticide application schedules, starting treatments when insects first appear, and continuing applications routinely throughout the season. Insecticides that are relatively inexpensive such as, for instance, toxaphene, are widely used in this manner.

Again, as in the foregoing example concerning the use of aldrin on corn, cotton growers consider this type of pesticide use a necessary protection of their crop, while from a biological and ecological viewpoint, the use may be at least partially wasteful, or even counterproductive (if it eliminates beneficial insects and thus results in a more severe pest insect problem). Integrated pest management programs are currently being developed and employed to overcome these problems (see pp. 119-121 of this report).

E. Other Wasteful Uses

Pesticides may be used wastefully, or released into the environment without redeeming benefits in a variety of additional ways, such as through breakage of, or spillage from containers; improper cleaning of application equipment; dumping of unwanted concentrated or dilute products; incomplete emptying of containers, measuring cups, spray tanks, hoppers, etc.; miscalibration; unnecessary overlapping of application swaths; etc. All of these potential sources of waste are common to all pesticides.

In addition, unwanted releases of pesticides into air, water and/or soil may occur in the course of production, formulation, packaging, transportation, warehousing and distribution of these products. These potential pesticide escape routes are outside of the scope of the present study but have recently been investigated in several other projects (including citations to 1971 MRI/RvR case study, and other recent MRI projects).

IX. ALTERNATIVES TO CHEMICAL PESTICIDES

A. Introduction

Very few, if any plants cultivated by man for the production of food or fiber or for other purposes are free from attack by pests that threaten to decrease yields, quality and/or aesthetic value of the plantings. Cultural, mechanical and other methods for combating such pests have been employed by growers around the world for centuries. Furthermore, naturally occurring predators, parasites and pathogens of pest organisms have been operating in undisturbed ecosystems to limit population levels of pests.

Some of the age-old techniques continue to be employed at this time. A number of additional alternatives to the use of chemical pesticides, or to sole reliance on them, have been developed more recently. Also, there is increasing interest in combining different pest control techniques in integrated pest management systems. General aspects of the major individual nonchemical crop protection and pest control methods, and of integrated pest management are discussed in this chapter.

B. Cultural Methods

Cultural methods, also referred to as "environmental manipulation", to reduce or eliminate pest damage to crops include (a) selection of planting and harvesting dates for crops so as to favor crop plants and to disrupt pests' life cycles; (b) selection of appropriate fertilizers and fertilizer application dates; (c) timing of plowing, tilling and cultivating so as to favor the crop and destroy the pest(s); (d) crop rotation; (e) fallowing; and others.

Plowing, tilling and/or cultivating involve soil movement and often result in increased soil erosion. While these measures may reduce the need for pesticides, they may, on the other hand, increase the migration of pesticide residues from the area if the top layer of soil (which is most affected by sheet erosion) contains pesticide residues from previous applications.

Cultural methods are most widely used for the control of weeds. They are generally less effective against insects. Except for crop rotation, they offer little help against most nematodes and plant diseases.

C. Physical and Mechanical Methods

Mechanical procedures to combat pests include (a) removal of weed seeds from crop seeds by hand or by mechanical equipment; (b) collection of insect egg masses, larvae or adults by hand; (c) removal of weeds from crops by pulling or hoeing by hand, or by harrowing or other mechanical means; and (d) control of weeds, insects or diseases by flooding or, in the case of limited quantities of soil, by steam sterilization. Pests affecting man or animals may be controlled by screens, sticky bands, fly swatters, rodent traps, etc.

Such methods of pest control generally are effective only if pest infestations are light, if only small areas are involved, and/or if human labor is readily available and economically feasible.

D. Resistant Crop Varieties

The breeding of crops resistant to pests is, in theory, one of the most promising techniques for the control of insects, diseases, and nematodes, but the technique offers less hope in regard to weeds. Crop varieties resistant to certain nematodes, insects, or diseases have been produced and continue to be produced by plant breeders in many countries. "Resistance" of the crop may consist of immunity or resistance against attacks by the pest, or of tolerance of the crop to the presence of the pest.

On the other hand, modern plant breeding has brought additional problems in regard to crop protection. Plant breeders usually strive first for high yield capacity and high quality in the crops on which they work. Often, higher yielding varieties are more susceptible to pests. The use of other agricultural production inputs, such as fertilizers and irrigation, results in denser, lusher growth that makes stands of such crops even more susceptible to many pests. Breeding pest resistance into new and higher yielding crop varieties may be undertaken as a secondary goal, but this reincorporation of resistance factors from the lower yielding strains which carry resistance genes is a difficult and time-consuming process. Often, the breeding of pest resistance is not attempted because the use of chemical pesticides is taken for granted and is included among the conditions under which prospective new strains and varieties are selected and tested.

On balance, modern breeders of agricultural crop varieties have without question made invaluable contributions to the improvement of quantity and quality of agricultural and horticultural production, but in regard to exposure of crops to pest damage, they have probably created about as many problems as they have solved. This conclusion is substantiated by the results of a recent study on the genetic vulnerability of major U.S. crops conducted by a committee of the National Academy of Sciences chaired by Horsfall.[59]

E. Predators and Parasites

Many insect pests have natural enemies that control their population levels and these natural enemies are an important factor in maintaining a dynamic balance among populations of plants and animals in an ecosystem. These naturally occurring control factors represent one of the greatest resources for pest suppression. The deliberate use of insect predators and parasites has received much attention in recent years (DeBach,[60] Doutt,[61] Geier,[62,63] Salier[64]).

Successful suppression or control by parasites and predators has been reported for over 100 arthropod pests, and for several species of weeds. There are three major ways of using this technique, i.e., (1) importation and colonization of parasites and predators against alien pests, (2) mass culture and periodic colonization (this technique is especially promising in closed systems such as greenhouses), and (3) conservation and augmentation of naturally present parasites and predators.

To apply any or all of these techniques successfully requires a thorough understanding of the life cycles of the organisms involved, including predators, parasites, host pest(s) and host plants. In this connection, the study of life tables for insects (Varley[65]) and of insect population dynamics (Varley and Gradwell[66]) has received much attention.

"Beneficial" insects have also been employed successfully against some weed species. However, this technique is currently most promising for the control of arthropod pests. It does not appear to offer promise against plant diseases.

F. Insect Pathogens

Two types of microorganisms pathogenic to insects have been developed and are in limited commercial use on several crops today, i.e., preparations of *Bacillus* species, and nuclear polyhedrosis viruses.

Several commercial products based upon *Bacillus thuringiensis* are currently available on the U.S. market. These products are exempted from the requirement of a tolerance and are registered for the control of lepidopterous insects on a considerable number of crops. The main deterrent to their use is that these bacterial products cannot effectively compete against chemical insecticides registered for the same control purposes. Growers are familiar with the chemical insecticides and their more rapid mode of action, and chemical insecticides are often less expensive per unit of control.

Preparations based on *Bacillus popilliae* and several other *Bacillus* species are under commercial development, but have not yet reached the volume of use of *Bacillus thuringiensis* preparations.

Several nuclear polyhedrosis virus preparations are available in the U.S. for control of cotton bollworms, *Heliothis* spp. These products are not widely used at this time. Problems concerning their large scale production, formulation, storage stability, application timing and methods, stability after application, and safety precautions remain to be resolved. Development work is in progress on a number of other insect viruses, including those of the cabbage looper, *Trichoplusia ni*; the alfalfa looper, *Autographa californica*; the Douglas fir tussock moth, *Hemerocampa pseudotsugata*; and several others.

Bacillus preparations are of interest to growers, especially for the control of lepidopterous insects on lettuce and cole crops close to harvest when there may be restrictions on the use of chemical insecticides. So far as application timing and technique is concerned, Bacillus preparations can be used as direct substitutes for chemical insecticides for the uses for which they are registered, or even combined with chemicals in the spray tank.

On the other hand, the virus preparations known to date do not work well if they are used in the same manner as chemical insecticides. They normally work best as components of complete integrated pest management systems.

Microbial pathogens useful for the nonchemical control of weeds or plant diseases have not been commercially developed to this date.

G. Sterilization

Males and females of a number of insect species can be sterilized by chemicals or by irradiation. Application of this method for insect control in the field involves (1) mass rearing of the pest insect, (2) sterilization, and (3) mass release of sterilized insects in the area of infestation. If a significant percentage of the target insect population is sterile the rate of reproduction will be reduced, and a decline in population will result. The sterilization process has to be controlled in such a manner that the sterilized individuals remain sexually competitive with untreated individuals in the wild population, while completion of the reproductive cycle is disrupted.

This method has been used successfully for the eradication of the screw-worm, *Cochliomyia hominivorax* (an important livestock pest), from several isolated tropical islands. It was subsequently used on a larger scale to suppress the screw-worm in the southeastern states and in the western gulf states. The existence of a small Florida wintering area for the screw-worm made this method of control very successful in the southeast, but a much more difficult task lies ahead in the Texas area. The sterilization technique is currently in pilot scale or full field use against several other insects, including the Mexican fruit fly, *Anastrepha ludens*; the pink bollworm, *Pectinophora gossypiella*; and the cotton boll weevil, *Anthonomus grandis*.

In each of the above cases, the logistics problems are formidable. By its very nature, the sterilization technique has to be used on an area wide basis. Thus far, this has limited its practical application to large-scale programs funded and executed by federal government agencies. Extension of the technique to other pest problems is not likely to occur rapidly. However, research activity in the field continues, and it is possible that the sterilization method may contribute to solving future insect problem.

Some work is in progress toward applying sterilization methods for the control of pest bird populations.

H. Insect Growth Regulators

Hormones regulate essential physiological processes such as growth, molting and reproduction of insects. The potential of such substances for control of insects has been recognized and developed by entomologists and biochemists in the United States and in Europe for a number of years (Bowers,[67] Menn and Beroza,[68] Robbins[69]). Several commercial companies in this country and elsewhere are actively engaged in the development and tryout of synthetic insect growth regulators for insect control. Promising results have been reported, and one chemical is currently in pilot scale commercial tests under an experimental permit from the Environmental Protection Agency for the control of mosquito larvae. It is reported that in this use, the product competes economically with fuel oils, and that it is completely effective against mosquito larvae resistant against conventional insecticides. Promising results have also been reported against fly species breeding in manure when the chemical was orally fed to cattle in small quantities.

Insect growth regulators have also been tested extensively for control of plant-feeding lepidopterous insects. However, results in this field so far have been less promising because, in this case, the larval stage of the insect is the economically damaging stage, and the insect's life cycle is disrupted only after it has already done the damage.

I. Pheromones, Attractants, and Repellents

Pheromones are chemicals used for communication between two or more animals of the same species. Among animals, pheromones are more important modes of communication than vision or sound (Shorey[70/]).

As possible tools of insect management or control, pheromones can be employed in different ways, i.e., to trap insects for diagnostic or for control purposes, or to disrupt their normal behavior, especially their mating behavior. Much work has been done to develop this potential for insect population management (Beroza,[71/] Shorey[70/]). Several pheromone preparations are currently in semicommercial or commercial use, including boll weevil pheromones in integrated cotton pest management, and fruit insect pheromones in traps for monitoring purposes in fruit orchards. An application is currently pending for an experimental permit for the use of traps baited with codling moth attractant for population reduction of this insect in the field.

Insects may also be influenced by attractants that are not pheromones, for instance, feeding attractants such as sugar, molasses or other sweet materials used in poisoned fly baits or sticky fly bands; protein hydrolysates used to attract fruit flies; etc. Such materials have been employed in place of chemical insecticides in some instances, or as a means to reduce the quantity of chemical insecticide required for control in others. In some cases, molasses appears to provide some protection against inactivation by UV light to chemicals or microorganisms if it is added to the spray mixture, an additional bonus from its use.

Other substances are known to have the opposite effect, i.e., to repel insects. Such chemicals are used in insect repellent products for human use or for the protection of livestock and domestic animals. Other chemicals are used to repel pest birds, dogs, and other animals.

Pheromones and attractants offer considerable promise as alternatives to chemical insecticides in some instances, but probably even greater promise as components of integrated pest management systems, in conjunction with chemical insecticides and/or other control techniques.

Attractants or repellents have not shown promise thus far for the control of soil insects, nematodes, weeds or plant diseases.

J. Antimetabolites and Antifeeding Agents

Antimetabolites and antifeeding agents are chemical substances that interfere with the nutritional or developmental processes of living organisms.

Antimetabolites inhibit the utilization of nutrients, usually by antagonistic action. They are chemically similar to essential nutrients and, when introduced into a biological system, prevent the nutrients from performing their normal functions. This appears to be an interesting approach from the theoretical standpoint, but no pest antimetabolites are in commercial use at this time.

Antifeeding agents, also called feeding deterrents, are designed to prevent pests from feeding on their normal host plants, thus eliminating the damage rather than the pest. Conceptually, this approach has considerable appeal. Antifeeding agents would be highly specific and would affect only insects attacking the crop being protected. Such use would not harm parasites, predators, or other beneficial insects, nor reduce the target insect population away from the treated target crop, thus allowing natural parasites and predators to continue to thrive on the species. However, no antifeeding agents are in, or nearing commercial use in the U.S. to this date. Thus, they are not available at this time as potential substitutes for chemical insecticides.

No substances of a comparable mode of action have been suggested for the control of weeds, plant diseases, or other pests.

K. Integrated Pest Management

Research workers and practitioners in the field of crop protection and pest control increasingly agree that the nonchemical methods of pest control are not likely to be effective substitutes for chemical pesticides by themselves; they will work best in conjunction with one or more other (chemical or nonchemical) pest control tools in integrated pest management systems. C. W. Huffaker, one of the pioneers of this concept, describes it as "The system of pest management that will bring the most benefits, at the most reasonable cost, on a long-term basis, to the farmer and to society". In this approach, the best of all available control techniques are to be brought to bear against pest problems, instead of sole reliance on chemical pesticides, or on any other single technique alone.

Much research and field work on integrated pest management has been done in recent years, with primary emphasis on biological aspects such as life cycles and life tables of the insects involved (both beneficial and injurious), and the biological effects of individual system components on the whole. Comparatively much less information is available on operational, economic, and financial requirements of integrated pest management systems. Many problems remain to be resolved; some examples are (1) determining the minimum effective scope of a practical program, (2) determining how to obtain and organize farmer cooperation, and (3) determining how to translate theories, principles, and research data into practical, economically viable programs at the grower level. Other thorny questions currently unanswered pertain to the future roles of the Federal/State Cooperative Extension system, the land-grant universities, the chemical industry, and independent pest management specialists in the further development and practical implementation of integrated pest management.

Integrated pest management programs focused on insect control are operational at the grower level at the present time in several cotton growing areas, especially in the southern and western parts of the cotton belt, and in several fruit growing areas. On cotton, as well as on fruit crops, the adoption of integrated pest management was greatly facilitated or even necessitated by the failure of chemical pesticides alone because of the development of resistance by target pests. The integrated pest management concept has not been reduced to practice in most other crops and areas. However, much research and development work is currently in progress, and it is anticipated that integrated pest management will make much additional progress, and see application on an increasingly larger scale in the near future.

The integrated pest management concept is presently much further advanced in regard to insect and mite pests than in regard to weeds or plant diseases. It is much discussed in regard to the latter fields, however. One school of thought among weed scientists advocates weed control on an area-wide basis, including all noncrop areas and fields not in production. By pursuing this course, weed seed reservoirs would hopefully be eventually depleted and the weeds thus eliminated. Proponents of this course admit that in the near term heavier use of chemical herbicides may be required, but claim that, in the long run, the need for herbicides and the costs of crop production would both be reduced.

Other weed scientists feel that weeds should be controlled only to the extent necessary in productive fields, and that the least possible disturbance of the ecosystem is the best course of action in the short as well as in the long run. This view seems to be shared by many ecologists (van Emden and Williams72/).

Weed control has never relied on chemical pesticides quite to the same extent as insect control in some of our intensive cropping systems.

Growers generally still use most of the cultural and mechanical farming practices summarized in Section B above with a view to reducing weed pressure, in conjunction with chemical herbicides as needed. In other words, "integrated weed management" has largely been a standard farming practice long before it was labeled as such. At most land-grant universities and in the extension service, weed scientists are usually associated with agronomy, botany or plant physiology departments. These organizational arrangements at the academic level have probably contributed to the greater degree to which weed control has been researched, taught and practiced as an interdisciplinary systems approach than has the insect control. Entomology is usually established as a separate department at the state universitites, and a separate Entomology Research Division existed within the U.S. Department of Agriculture until recently.

Specific integrated pest management programs for the control of nematodes, plant diseases or other pests have not been developed. Many current pest control practices in these fields, however, combine the use of chemicals with good husbandry, sanitation, crop rotation and other nonchemical pest control or suppression methods.

In summary, a great deal of interest currently exists in integrated pest management in all areas of crop protection and pest control. Publicly funded, multi-university research and development programs have spurred cooperation among the biological disciplines involved in crop protection to a degree unprecendented in this age of specialization. Cooperation with the socio-economic disciplines, however, appears to be lagging. Nevertheless, the overall progress in integrated pest management during the last few years has been rapid and encouraging and, if continued vigorously, should result in the more judicious use of pesticides in the future--a development that would benefit the American farmer as well as our society as a whole.

X. CASE STUDIES OF 25 SELECTED PESTICIDES

In this chapter profiles of the production, distribution, use and environmental impact potentials of 25 pesticides are presented. The criteria for the selection of these 25 are presented in Appendix A, and the order of presentation of the case studies is as shown below:

Pesticide	Page
1. Aldrin	126
2. Carbaryl	133
3. Carbofuran	141
4. Chlordane	149
5. Diazinon	157
6. Disulfoton	166
7. Malathion	173
8. Methyl parathion	181
9. Parathion	189
10. Toxaphene	196
11. Alachlor	205
12. Atrazine	211
13. Bromacil	218
14. 2,4-D	225
15. Diuron	232
16. MSMA	238
17. Sodium Chlorate	247
18. Trifluralin	257
19. Captan	264
20. Creosote	271
21. Maneb	298
22. Pentachlorophenol	308
23. p-Dichlorobenzene	320
24. Methyl bromide	327
25. Organotin compounds	334

Each of the case studies is presented in the same general format. The order of the sections of each case study is:

A. Product Description
B. Manufacturers and Plant Locations
C. Production Methods and Waste Control Technology
D. Formulation, Packaging and Distribution
E. Use Patterns, including Materials Flow Diagram
F. Environmental Impacts
G. Alternatives to Use

The case studies were prepared on the basis of: questionnaires (as described in Chapter IV) completed by most of the active ingredient manufacturers; personal and telephone interviews in every case with manufacturers or formulators of the subject pesticide--either during 1973 or during a related study[1/] on 14 of these pesticides during 1971; literature reviews; and our general knowledge of the chemistry, use patterns, and effects of pesticides.

The pesticide flow diagrams warrant a brief explanation. They are designed to give an overview of the flow of materials involved in the production and use of the intensive-study products in terms of quantities and geographic distribution.

Two different systems of graphic description have been employed:

(1) The "arrow system" has been used for products for which there is only one manufacturing plant in the U.S. The flow of raw materials to the manufacturing site is shown by unshaded flow lines. The flow of pesticide active ingredient to the areas of use is shown by shaded arrows which are graduated in proportion to the volume involved. In cases where the geographic distribution of certain uses is not known (examples: some home and garden uses), or is too small to be subdivided by regions, these uses have been shown by single arrows pointing into a geographically "neutral" area.

(2) The "bar system" has been employed for products that are manufactured in more than one plant in the U.S. Locations of the manufacturing plants are identified by stars. Use of the product, regardless of the origin of the supply, is shown by bars graduated in proportion to the use volume, placed within the geographic area of use. In this system, it was not possible to include the flow of raw materials to each manufacturing site in the diagram. However, this information is given in the text where applicable and available.

In the lower left hand corner of each flow diagram, a small table summarizes the 1972 estimated U.S. production, imports, exports, and U.S. supply.

In cases where there are both exports from, and imports into the U.S. of the same product, only the net import or export quantity has been shown in the flow diagram, identified as "net export" or "net import," respectively.

For each product, the U.S. use is broken down by the following geographic regions:

Northeast (9 states):

Maine
New Hampshire
Vermont
Massachusetts
Rhode Island
Connecticut
New York
New Jersey
Pennsylvania

North Central (12 states):

East

Ohio
Indiana
Illinois
Michigan
Wisconsin

West

Minnesota
Iowa
Missouri
North Dakota
South Dakota
Nebraska
Kansas

Southeast (8 states):

Maryland
Delaware
Virginia
West Virginia
North Carolina
South Carolina
Georgia
Florida

South Central (8 states):

Kentucky
Tennessee
Arkansas
Alabama
Mississippi
Louisiana
Oklahoma
Texas

Northwest (8 states):

Montana
Idaho
Wyoming
Colorado
Utah
Washington
Oregon
Alaska

Southwest (5 states):

New Mexico
Nevada
Arizona
California
Hawaii

The boundaries between regions are indicated on each diagram by dark shading of the appropriate state lines.

Where there is a substantial use of a given product within one of the major regions, the geographic distribution is broken down further, in some cases by individual states, on others by groups of several states. In these instances, the boundaries between the use areas--either individual states or groups of several states--are indicated by light shading of the appropriate state lines.

Information on by-products generated in the course of producing the pesticide active ingredient has been included in the flow diagrams whenever available. In the case of single-plant products (arrow system), this information is given in terms of the estimated total quantity of by-products generated. In the case of multiple-plant products (bar system), the information is given in terms of pounds of by-products generated per pound of active ingredient produced.

An attempt to compile effluent discharge data for active ingredient manufacturers was generally unsuccessful. Each EPA region was contacted by letter requesting copies of the "Application for Permit to Discharge or Work in Navigable Waters and Their Tributaries" given by each pesticide manufacturer to the Corps of Engineers. A list of the specific companies and plant sites in which we were interested was given to each region with a request that they send us Parts A and B of Section II (as they were denoted in the Corps of Engineers Form). Each region replied by letter or telephone, or both, but only two regions were able to furnish permits. The other regions either did not have the permits on hand or simply did not have the manpower to perform the time-consuming task of copying and assembling them. The EPA Permits Program Division in Washington, D.C., was then contacted and was able to furnish a number of the permits we requested. In all, four permits were received from Region IX, 11 permits from Region VI and 13 from Washington, D.C. The permits from Region IX and Washington, D.C., were computer printouts which did not contain the information we needed.

CASE STUDY NO. 1. ALDRIN

A. Product Description

Chemical Name: 1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,6-dimethanonaphthalene

Trade Names: Aldrin

Pesticide Class: Broad spectrum insecticide; chlorinated hydrocarbon

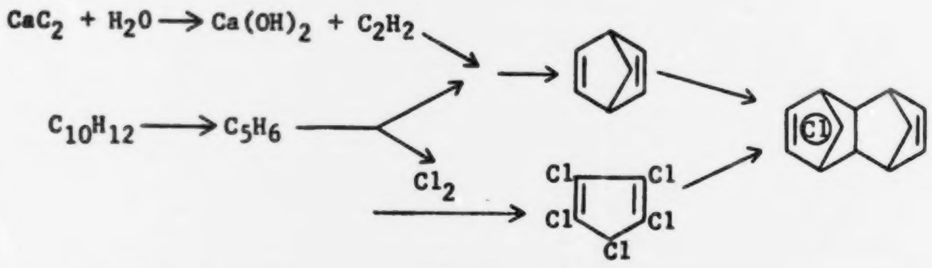
Properties: Solid, insoluble in water, very toxic; persistent in form of dieldrin

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Shell Chemical Company	Denver, Colorado	20 million lb	13 million lb

C. Production Methods and Waste Control Technology

Information on the production and waste control technology for aldrin have been reported.[1] The reaction chemistry is:


$CaC_2 + H_2O \rightarrow Ca(OH)_2 + C_2H_2$
$C_{10}H_{12} \rightarrow C_5H_6$
Cl_2
Cl
Cl
Cl
Cl
Cl
Cl
Cl

A production and waste schematic is shown in Figure 7. Aldrin is manufactured in dedicated equipment. Raw materials are received from various sources by rail, tank cars, and gondola cars. Liquid effluent is processed to reduce contained aldrin to the level of solubility. Liquid wastes presently (1974) go to an asphalt lined evaporation basin which is diked. During summer shutdown, aldrin production equipment is washed with toluene which goes to dieldrin manufacture. Damaged drums are cleaned as above, incinerated, flattened, and sold as scrap steel. Solid wastes go to EPA approved dump sites.

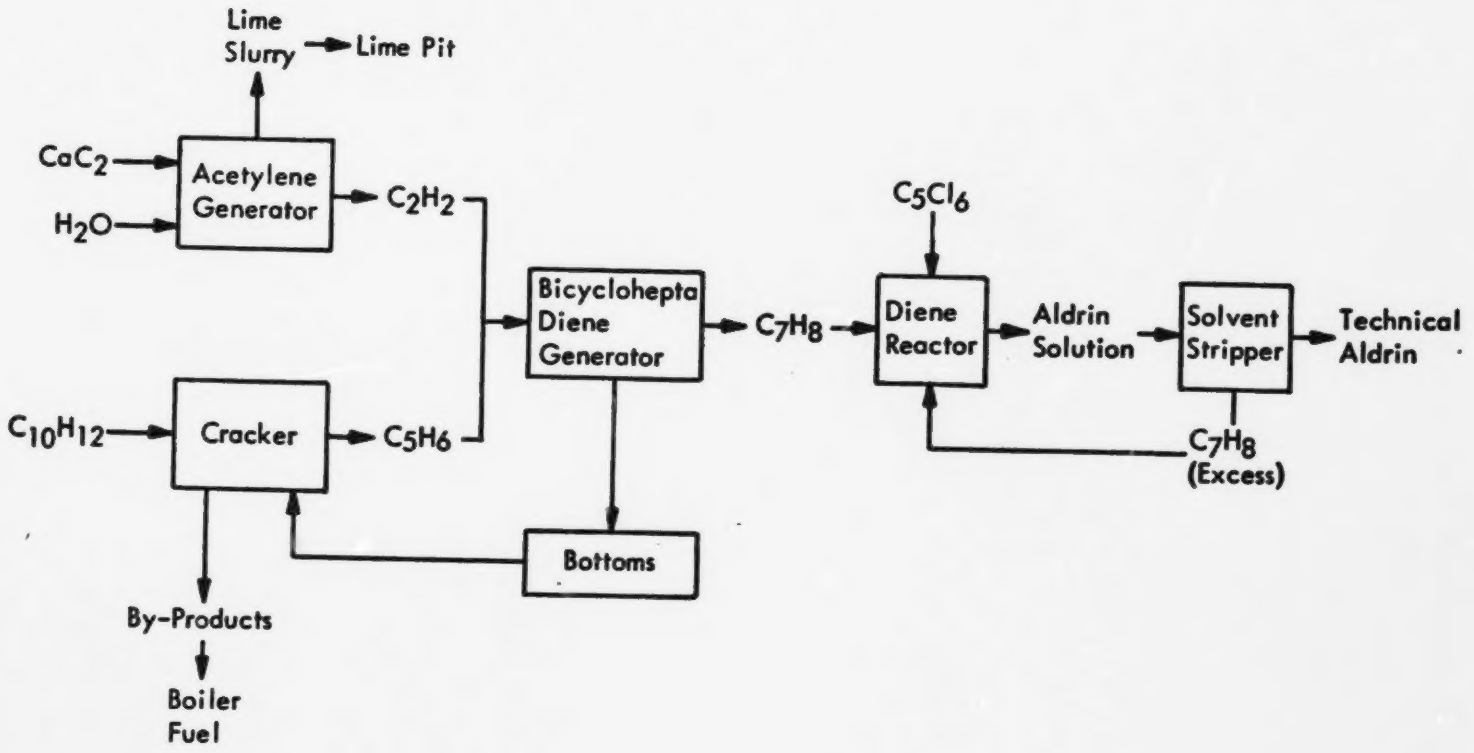

Lime Slurry
Lime Pit
CaC_2
H_2O
Acetylene Generator
C_2H_2
$C_{10}H_{12}$
Cracker
C_5H_6
Bicyclohepta Diene Generator
Bottoms
By-Products
Boiler Fuel
C_7H_8
C_5Cl_6
Diene Reactor
Aldrin Solution
Solvent Stripper
Technical Aldrin
C_7H_8 (Excess)

Figure 7 - Production and Waste Schematic for Aldrin[1]

D. Formulation, Packaging, and Distribution

Shell packages technical grade aldrin in 28 gal. fiber Mylar-lined drums. These are shipped by rail and truck. Aldrin is available in a 20% granular form and a 4 lb/gal. LFE (liquid fertilizer emulsion) packaged in 5-gal. cans and 5-, 30-, and 55-gal. lined drums. Aldrin is available as wettable powders, dusts, solutions, dry or liquid fertilizer mixtures; available in varying concentrations of AI. Shipment of the formulated products is primarily by truck. The major area of use for aldrin is in the cornbelt.

E. Use Patterns

General : Aldrin is one of the most economical and most widely used soil insecticides. Its principal metabolite is dieldrin, one of the most persistent of all pesticides.

Aldrin has been in large-scale commercial use in the U.S. and in many other countries for nearly 20 years. Agricultural uses accounted for an estimated two-thirds of the domestic consumption of aldrin in 1972.

Action : Broad-spectrum insecticide; contact, stomach and inhalation poison, believed to affect the central nervous system. Exact mechanism of action not known.

Target Crops : Major: Corn; protection of structures.
Minor: Sugarcane, tobacco; many other field, vegetable and fruit crops.

Target Pests : Many soil insects; termites; some foliar insects. In certain areas, corn rootworms, seed corn beetle, seed corn maggot, wireworms, rice water weevil, and other insects have developed resistance.

Application : Soil treatment; seed treatment; baits; foliar application; soil injection. Soil application by ground equipment; mostly broadcast, sometimes banded. Foliar application by ground or air equipment.

Rates of Application : Soil treatment: 2-5 lb AI/acre.
Seed treatment: 1-2 oz AI/bu seed.
Foliar treatment: 0.25-0.5 lb AI/acre.
Bait: 0.25 lb AI/acre.
Termite control: 0.5% AI.

Frequency : Usually one application per season.

Time of Application : Agricultural applications mostly spring and early summer; applications against termites year-around.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
13.0	None	0.3	12.7

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	--	0.3			0.3
SE	0.2	0.5			0.7
NC	10.7	0.3			11.0
SC	0.1	0.4			0.5
NW	--	0.1			0.1
SW	--	0.1			0.1
Totals	11.0	1.7	Negligible	Small	12.7

The materials flow diagram for aldrin is shown in Figure 8.

F. Alternatives

Chemicals : Against soil insects, other chlorinated hydrocarbon insecticides, especially heptachlor and chlordane (these are also effective against termites); furthermore, carbofuran, phorate and several other carbamate and organic phosphate insecticides may be effective against soil insects. Most of the latter do not have as broad a spectrum of efficacy as aldrin, provide less residual control, are considerably more expensive, and are not practical against termites.

Against foliar insects, there are a number of other chemical insecticides available for the same purposes for which aldrin is recommended.

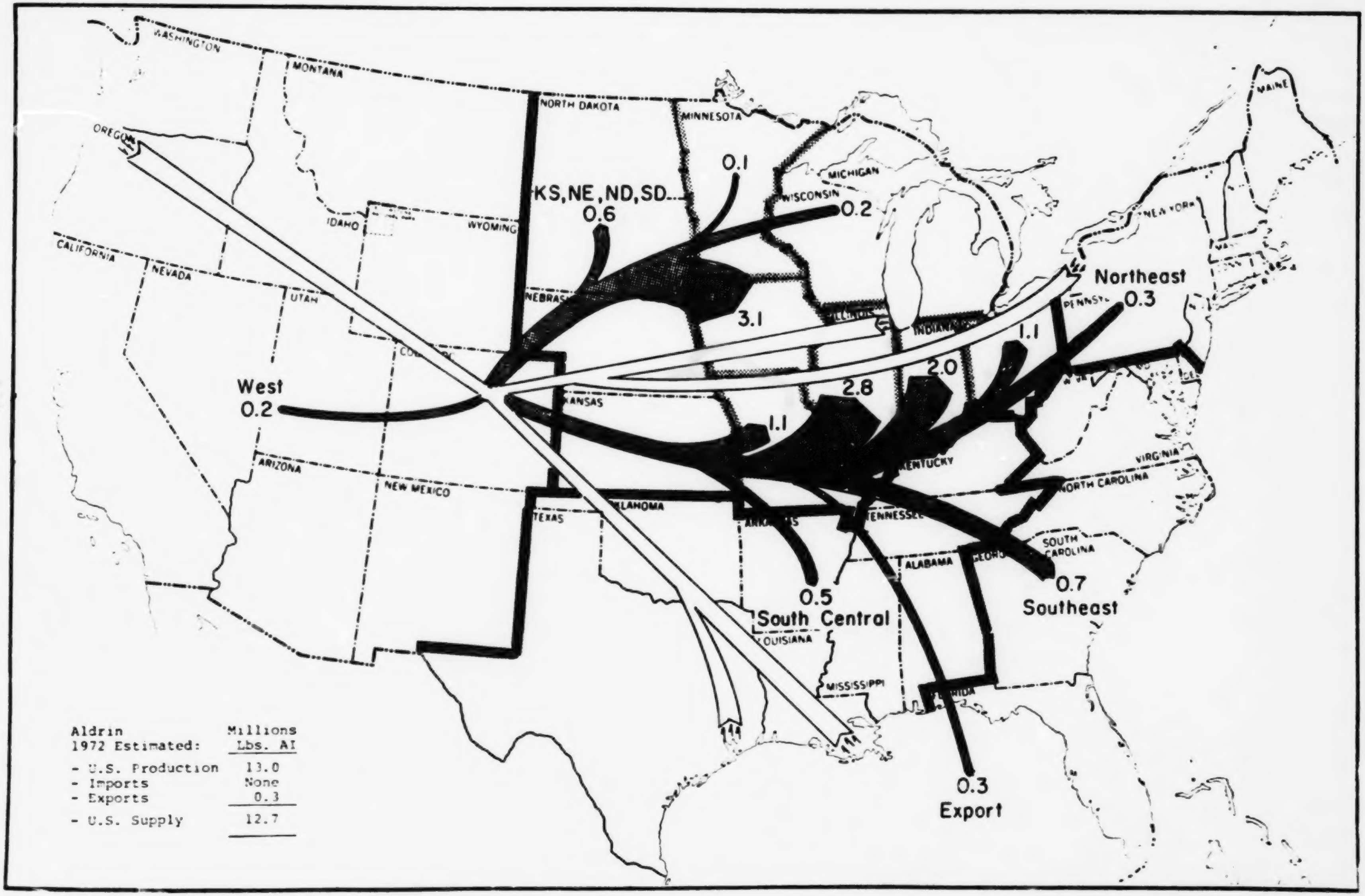

WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
NEBRASKA
COLORADO
KANSAS
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYL.
NEW YORK
MAINE
MICHIGAN
WISCONSIN
ILLINOIS
INDIANA
KS,NE,ND,SD
0.6
0.1
0.2
3.1
West
0.2
1.1
2.8
2.0
1.1
Northeast
0.3
0.7
Southeast
0.5
South Central
0.3
Export
Aldrin
1972 Estimated:
Millions
Lbs. AI
- U.S. Production 13.0
- Imports None
- Exports 0.3
- U.S. Supply 12.7

Figure 8 - Materials Flow Diagram for Aldrin, 1972

Nonchemical : No effective direct nonchemical methods of control of soil insects affecting agricultural crops have been developed to date. Crop rotation is an indirect measure to reduce soil insect damage. There are no effective nonchemical methods available for control of termites.

G. Environmental Impact Potential

Mammalian Toxicity : In acute toxicity tests, technical aldrin is highly toxic to laboratory animals by the oral, dermal and inhalation routes. It is mildly irritating to the eyes and to the skin. Most aldrin formulations require the signal word "Warning" on the label.

The chronic toxicity of aldrin has been studied extensively. Some investigators have reported a "minimal effect level" of 0.5 ppm in the diet of rats, 1.0 ppm in the diet of dogs. The Panel on Carcinogenesis of the Commission on Pesticides and their Relationship to Environmental Health (U.S. Department of Health, Education and Welfare) assigned aldrin to a category of pesticides "judged positive for tumor induction on the basis of tests conducted adequately in one or more species, the results being significant at the 0.01 level." Tolerances for residues of aldrin have been established for a number of crops, ranging from 0.02 to 0.1 ppm, 0.1 ppm for most commodities.

Nontarget Organisms : Aldrin is highly toxic to fishes, lower aquatic organisms, birds, wild mammals, and to soil insects. It is relatively nontoxic to other soil organisms. Aldrin and its principal metabolite, dieldrin, bioaccumulate and build up in food chains.

Aldrin is also highly toxic to bees and beneficial insects (predators and parasites) on direct contact, but this is not a problem in its predominant use as a soil insecticide.

Environment : The principal metabolite of aldrin is dieldrin, one of the most persistent pesticides. Aldrin residues in the soil persist for years. There is substantial carryover of aldrin residues to succeeding vegetation seasons.

Aldrin and its residues have a low propensity for movement away from treated areas by volatilization, leaching or surface run-off in water. However, the likelihood of migration of aldrin residues adsorbed on solids by way of soil erosion and sediment transport is substantial. Migration on solids by wind erosion is possible.

Both aldrin and dieldrin are subject to photo-decomposition, and are believed to be degradable by biological organisms as well as by nonbiological factors. However, the exact pathways are not known. The overall rate of degradation of aldrin/dieldrin is very slow and, consequently, aldrin/dieldrin residues in the environment are very persistent. In the National Soils Monitoring Program, residues of aldrin/dieldrin were found more frequently than those of all other pesticides. Aldrin/dieldrin residues have also been detected in many other samples of components of the environment, including plants, animals, air and water. In some instances, such residues have been found in places far removed from sites of application of aldrin or dieldrin.

Evaluation : No peculiar hazards to operators are known to be associated with the use of aldrin products in accordance with label directions.

The U.S. Department of Health, Education and Welfare Secretary's Commission on Pesticides and their Relationship to Environmental Health recommended that the usage of aldrin (and that of a number of other pesticides of similar properties) be restricted to specific essential uses that create no known hazards to human health or to environmental quality. A number of aldrin uses were cancelled several years ago. The U.S. Environmental Protection Agency has proposed to cancel most of the remaining use of aldrin. Administrative proceedings including exhaustive nationwide hearings on the benefits and risks associated with the use of aldrin are currently in progress. Witnesses who have testified to date have presented widely divergent views on the problem.

CASE STUDY NO. 2. CARBARYL

A. Product Description

Chemical Name: 1-Naphthyl N-methylcarbamate

Trade Names: Hexavin, Karbaspray, Ravyon, Septene, Sevin, Tricarnam

Pesticide Class: Insecticide; Alkyl carbamate

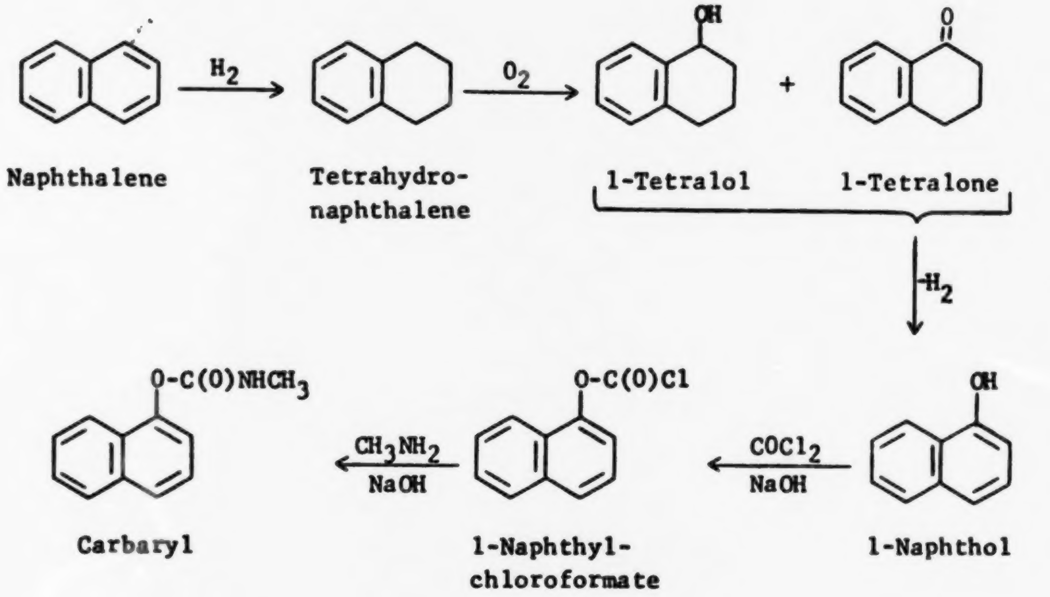
Properties: Solid; solubility in water: 40 ppm at 30°C; moderately toxic; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Union Carbide Corporation	Institute, West Virginia	65 million lb (estimated)	53 million lb

C. Production Methods and Waste Control Technology

Information on the production and waste control technology for carbaryl have been reported.[1] The reaction chemistry is:



H_2
O_2
OH
O
+
Naphthalene
Tetrahydro-naphthalene
1-Tetralol
1-Tetralone
$-H_2$
O-C(O)NHCH$_3$
CH_3NH_2
NaOH
O-C(O)Cl
$COCl_2$
NaOH
OH
Carbaryl
1-Naphthyl-chloroformate
1-Naphthol

A production and waste schematic is shown in Figure 9.

Union Carbide manufactures carbaryl by a combination of batch and continuous processes. Raw materials for production are made on-site and received by pipeline or tank car. All pesticide-containing waste water goes to the plant's secondary waste treatment system and then to a river. This effluent contains only 0.01-1 ppm carbaryl. Toxic vents are either flared or go to NaOH scrubbers. Nontoxic vents go to a condenser and are then vented to the atmosphere. Standard hoods are used in the packaging area and the recovered material is recycled. The heavy residue solid wastes are burned. One shutdown for cleaning is made per year, but numerous maintenance clean-ups are made, the washings go to the process waste treatment system.

D. Formulation, Packaging, and Distribution

Technical carbaryl is available in two forms: pelletized, 99% AI, packaged in a 50-lb bag, and concentrates of 50-97% AI, also in 50-lb bags. Both are shipped by rail and truck. Union Carbide provides the following formulations: Sevin® wettable powders of 50% and 80%; Sevin® 50% dust base; granules of 5% to 10%; Sevin® 80% and 85% sprayables, and 4 lb/gal flowable suspensions in oil and molasses. It is also available as baits.

E. Use Patterns

General	:	Carbaryl has been in large-scale use in the U.S. and in many other countries for more than 15 years. It is still the most widely used carbamate insecticide in the U.S. today. It has a broad spectrum of effectiveness on insects, is only slightly toxic to mammals, not persistent, and degrades rapidly in the environment after application. Its spectrum of insect control overlaps in part with that of some chlorinated hydrocarbon insecticides such as DDT, toxaphene and others.
Action	:	Broad-spectrum insecticide, contact and stomach poison, no systemic action. Reversible inhibitor of cholinesterase.
Target Crops	:	Soybeans; sweet corn; ornamentals and turf; field corn; forest and shade trees; cotton; deciduous tree fruits; many other field, vegetable, fruit and nut crop; poultry and pets.

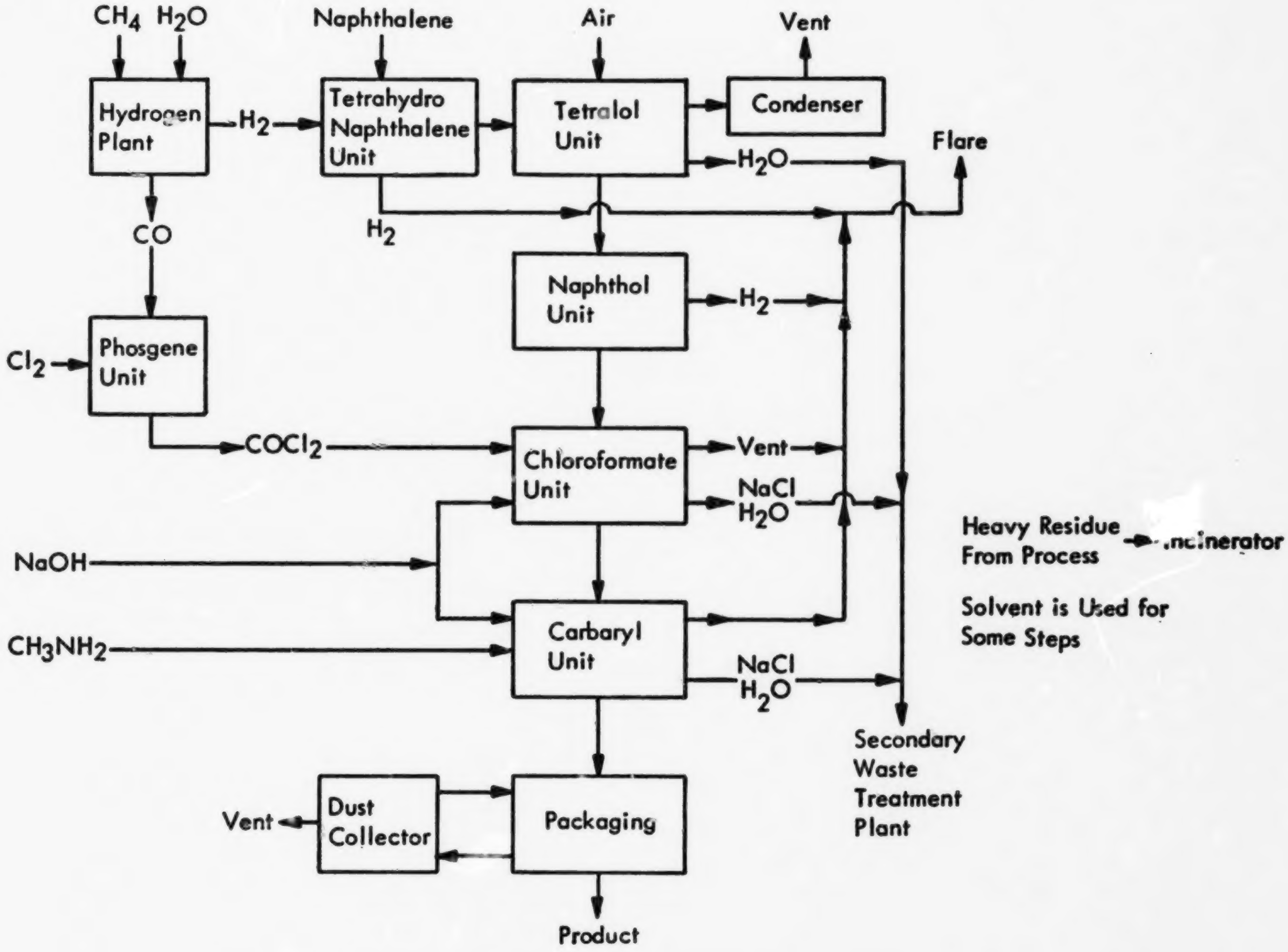

CH4
H2O
Hydrogen Plant
H2
CO
Naphthalene
Tetrahydro Naphthalene Unit
H2
Air
Tetralol Unit
Condenser
Vent
H2O
Flare
Phosgene Unit
Cl2
COCl2
Naphthol Unit
H2
Chloroformate Unit
Vent
NaCl H2O
NaOH
CH3NH2
Carbaryl Unit
NaCl H2O
Secondary Waste Treatment Plant
Heavy Residue From Process → Incinerator
Solvent is Used for Some Steps
Dust Collector
Vent
Packaging
Product

Figure 9 - Production and Waste Schematic for Carbaryl[1]

Target Pests : Corn earworm, armyworms, gypsy moth, European corn borer, cutworms, corn rootworm beetles, pink bollworm, leafhoppers, scale insects, many other insects. Mites, lice, fleas, ticks, bedbugs on and around poultry and pets. Ineffective against most aphids, plant-feeding mites, and flies. Some resistance of target pests.

Application : Largest volume use is foliar spray (wettable powders much more widely used than the flowable suspension) to agriculture crops, trees and forests by air or ground equipment. Much smaller quantities of AI go into baits, dusts and granules which are also applied by ground or air equipment. Dips, washes, sprays or dusts on animals.

Rates of Application : 1.0-2.5 lb AI/acre for most field, forage and truck crops (lower or higher rates labeled for some uses);
1.0 lb AI/100 gal. for most fruit crops;
2.0-5.0% dusts or 0.5-1.0% AI dips or washes for use on poultry and pets.

Frequency : 1-10 applications per season or per year.

Time of Application : Throughout the growing season on crops. On poultry and pets, throughout the year as required.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972):

U.S. Production	Imports	Exports	Domestic Consumption
53	None	28	25*

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGIONS

Region	Agricultural	Industrial, Commercial	Government Agencies	Sub-totals	Home and Garden[a]	Totals[a]
NE	1.5	0.2	0.3	2.0		
SE	7.5	0.2	0.2	7.9		
NC	4.5	0.2	0.1	4.8		
SC	3.5	0.2	0.2	3.9		
NW	0.7	0.1	0.1	0.9		
SW	1.3	0.1	0.6	2.0		
Totals	19.0	1.0	1.5	21.5	3.5	25

---

[a] Geographic distribution not known.

* Industrial sources have estimated the domestic consumption of carbaryl to be as low as 16.5 million pounds, but tend to confirm our production estimate and the comparable sizes of exports and domestic consumption.

The materials flow diagram for carbaryl is shown in Figure 10.

F. Alternatives

Chemicals : Many other chemical insecticides control some or many of the corp insects controlled by carbaryl, but carbaryl is unique in regard to its combination of properties, i.e., low mammalian toxicity, low persistence, and efficacy against many economically important *Lepidoptera* and *Coleoptera*.

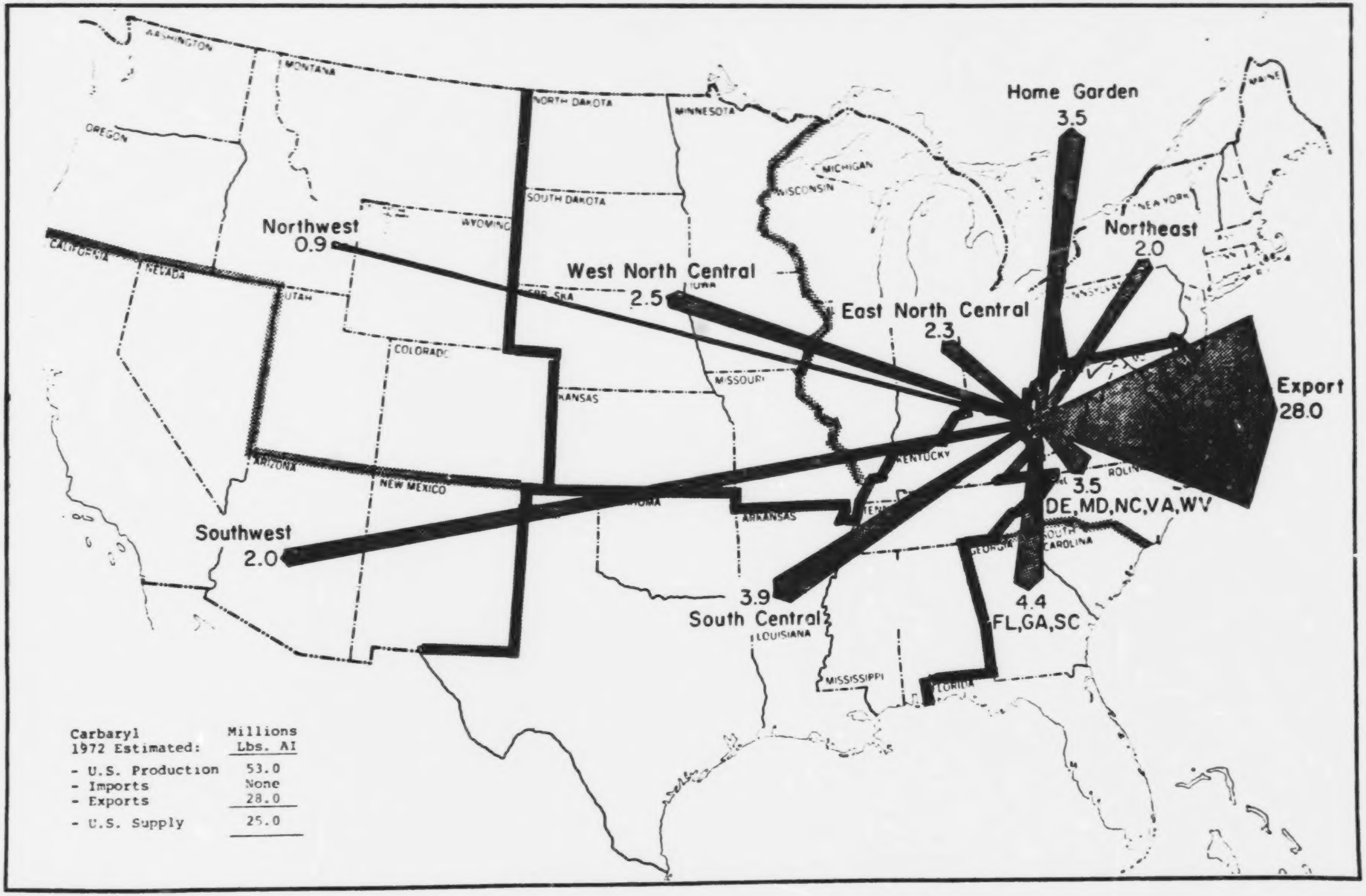
A number of other insecticides are effective against the insects on poultry and pets against which carbaryl is recommended.

Nonchemical : Biological control agents and integrated insect management methods are being developed and employed against some of the insects controlled by carbaryl, especially cotton and fruit insects.

No effective nonchemical alternatives have been developed to date for the control of insects on poultry and pets. Good sanitation and husbandry practices help, but may not be sufficient by themselves to prevent insect problems or abate existing ones.

G. Environmental Impact Potential

Mammalian Toxicity : Carbaryl is slightly toxic to laboratory animals in acute toxicity tests via the oral, dermal and inhalation routes. It is not irritating to the eyes, the skin, or the respiratory tract. No sensitization reactions or cumulative toxic effects have been reported. The most widely used carbaryl formulations carry the signal word "Caution" on the label. In chronic toxicity tests, the no-effect level in the diet was 200 ppm for rats in a 2-year study, 400 ppm for dogs in a 1-year study. There were no adverse effects on the reproduction of rats fed 200 ppm in their diet for 3 generations. Tolerances for residues of carbaryl have been established for a large number of commodities, ranging from 1 to 100 ppm, 5 to 10 ppm for most crops.


Home Garden
3.5
Northeast
2.0
Export
28.0
East North Central
2.3
West North Central
2.5
Northwest
0.9
3.5
DE,MD,NC,VA,WV
4.4
FL,GA,SC
3.9
South Central
Southwest
2.0
WASHINGTON
OREGON
CALIFORNIA
NEVADA
MONTANA
UTAH
WYOMING
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IOWA
MISSOURI
KANSAS
ARKANSAS
LOUISIANA
MISSISSIPPI
WISCONSIN
MICHIGAN
KENTUCKY
NEW YORK
MAINE
SOUTH CAROLINA
GEORGIA
FLORIDA

Carbaryl 1972 Estimated:	Millions Lbs. AI
- U.S. Production	53.0
- Imports	None
- Exports	28.0
- U.S. Supply	25.0

Figure 10 - Materials Flow Diagram for Carbaryl, 1972

The Panel on Teratogenicity of Pesticides of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health (U.S. Department of Health, Education and Welfare) reported that carbaryl produced teratogenetic symptoms in tests on mice and dogs. These effects appeared to be dose-related and were not seen at the lower rates of application in these tests. Extensive tests with monkeys have failed to produce teratogenesis in primates. The possible significance of these findings in regard to human health has not been established.

Nontarget Organisms : Carbaryl is slightly toxic to fishes, moderately toxic to lower aquatic organisms, relatively nontoxic to birds, wild mammals and soil organisms. It is highly toxic to honeybees and to some, but not all, beneficial insects (predators and parasites). There are no data on its possible buildup in food chains. Because of its lack of persistence and rapid metabolism, this is not likely to occur.

Applied between 10 and 25 days after full bloom of apples, carbaryl will produce fruit thinning. A single application needs to be carefully timed if this is desired. If apple thinning is to be avoided, carbaryl should not be used until at least 30 days after bloom.

Environment : The insecticidal effectiveness of carbaryl persists for about 3 to 10 days on treated plants, 3 to 4 months on protected inert surfaces, and 3 weeks in the soil. The half-life of soil residues is of the order of 7 to 10 days. There is no carryover of soil residues from one season to the next. Carbaryl degrades rapidly in the environment after application and is not persistent.

Carbaryl residues may dissipate in part through volatilization. Leaching from the soil is possible based on laboratory studies, but is not likely to occur to a significant extent under field conditions because carbaryl is not recommended for incorporation into the soil and, if it does penetrate into soil, is rapidly degraded. Likelihood of movement of carbaryl residues from treated fields by surface run-off in water or on solids likewise is low.

Carbaryl is degradable by biological organisms as well as by nonbiological factors including sunlight. Carbaryl appears to be degraded by several different pathways. A number of metabolites and degradation products have been identified; all are less toxic to laboratory mammals than the parent compound.

Evaluation : The handling and use of carbaryl formulations in accordance with label directions does not present any serious hazards to operators. No other serious hazards to human health have been attributed to the use of this insecticide. There are no indications or reports of hazards to terrestrial or aquatic ecosystems outside of target areas and their vicinities from the proper use of carbaryl.

CASE STUDY NO. 3. CARBOFURAN

A. Product Description

Chemical Name: 2,3-Dihydro-2,2-dimethyl-7-benzofuranyl methyl carbamate

Trade Names: Furadan

Pesticide Class: Systemic insecticide, acaricide and miticide; a cholinesterase inhibitor

Properties: White, odorless crystalline solid; MP 150°C; solubility in water is 250 to 700 ppm at 25°C

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Agricultural Chemical Division, FMC Corporation	Baltimore, Maryland Middleport, New York	7 million lb (estimated)	6 million lb

C. Production Methods and Waste Control Technology

Carbofuran is a relatively new product, still under patent, and manufactured only by FMC, Agricultural Chemical Division. Agricultural Chemical Division officials declined to reveal details of the production method, but supplied copies of pertinent patents covering their processes. The reaction sequence below and the flow chart shown in Figure 11 were developed from the patents. The steps through the benzofuranol are apparently conducted in Baltimore and the final step is completed in Middleport. A major plant expansion was underway in late 1973.

The reaction chemistry is believed to be:

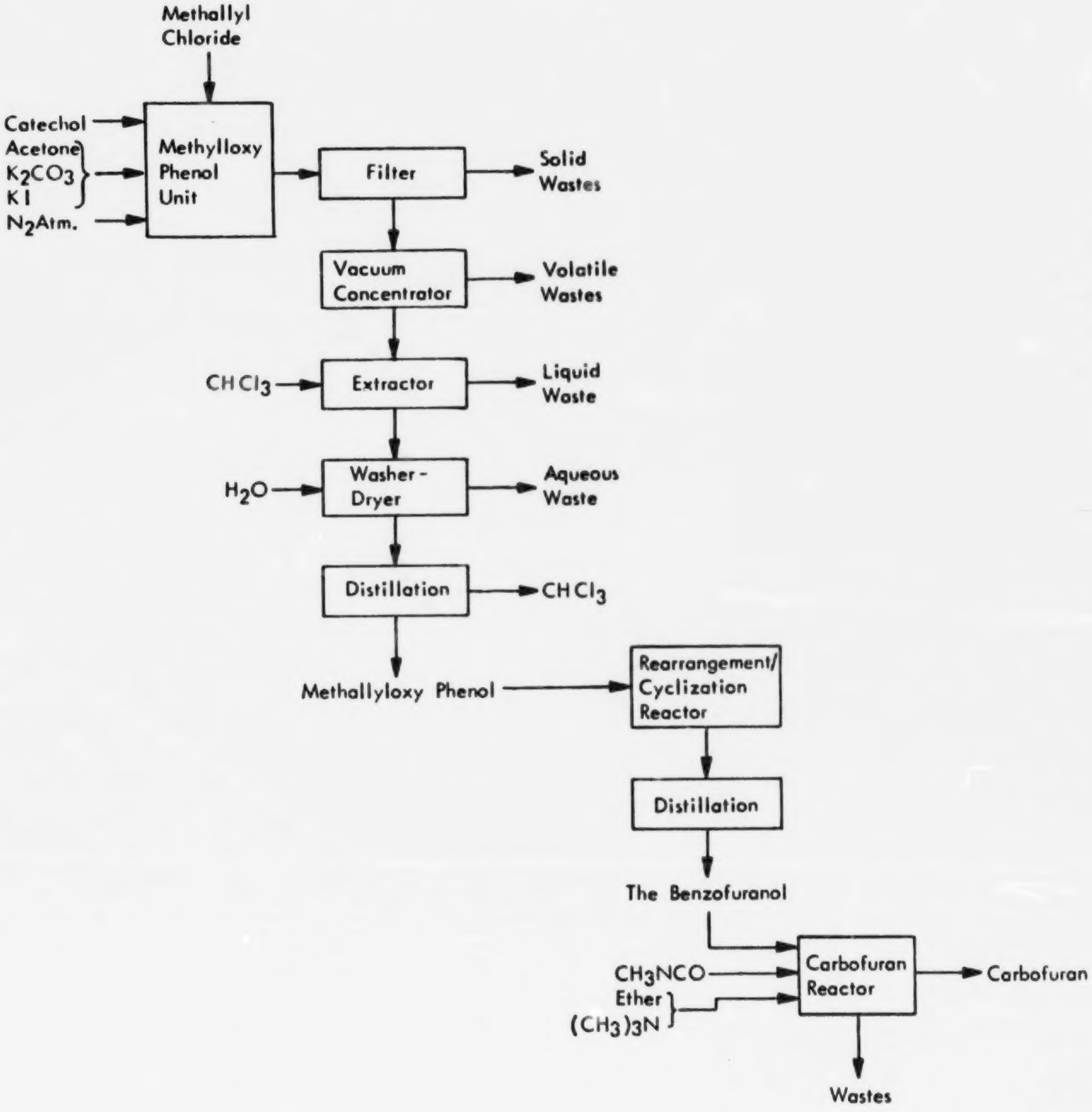
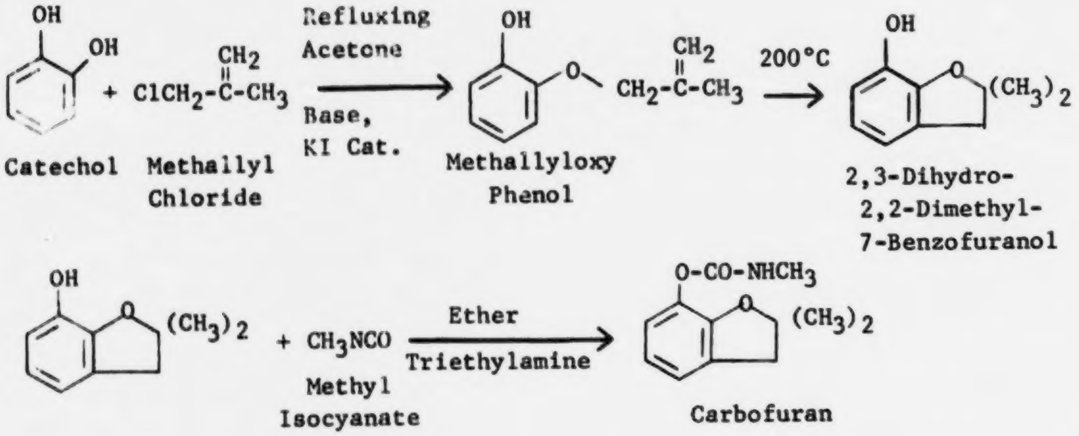

Methallyl Chloride
Catechol
Acetone
K_2CO_3
KI
N_2 Atm.
Methylloxy Phenol Unit
Filter
Solid Wastes
Vacuum Concentrator
Volatile Wastes
$CHCl_3$
Extractor
Liquid Waste
H_2O
Washer-Dryer
Aqueous Waste
Distillation
$CHCl_3$
Methallyloxy Phenol
Rearrangement/ Cyclization Reactor
Distillation
The Benzofuranol
CH_3NCO
Ether
$(CH_3)_3N$
Carbofuran Reactor
Carbofuran
Wastes

Figure 11 - Production and Waste Schematic for Carbofuran


Catechol
Methallyl Chloride
Refluxing Acetone
Base, KI Cat.
Methallyloxy Phenol
200°C
2,3-Dihydro-2,2-Dimethyl-7-Benzofuranol
Methyl Isocyanate
Ether
Triethylamine
Carbofuran

The pollution control system for liquid waste streams consists of neutralization, concentration equalization and settling to remove solids before discharge.

D. Formulation, Packaging, and Distribution

The following formulations are known: Furadan 2G (2% carbofuran, 50-lb bag), Furadan 3G (3% carbofuran, 50-lb bag), Furadan 5G (5% carbofuran, 30-lb bag), Furadan 10G (10% carbofuran, 30-lb bag), and Furadan 4 flowable (4 lb carbofuran/gal., 1-gal. container). The 10% granules are used most widely.

FMC did not provide information on their shipping procedures.

E. Use Patterns

General : Carbofuran is the most effective insecticide currently available against corn rootworms, including forms resistant against other insecticides. It was commercially introduced only during the last few years. Its use has increased rapidly and continues to increase, mainly because of its superior effectiveness against corn rootworms and other soil pests as well as its systemic properties for control of foliar feeding pests. It reached the market at a time of increasing demand and prices for corn.

Emulsifiable concentrate formulations cannot be made due to lack of solubility of carbofuran in commonly used non-polar organic pesticide solvents.

There were no significant nonfarm uses of carbofuran in 1972.

Action : Broad-spectrum insecticide, miticide and nematocide; contact, stomach and plant-systemic toxicant. Reversible inhibitor of cholinesterase.

Target Crops : Corn; alfalfa; peanuts; rice; sugarcane; tobacco; potatoes; sugar beets; sorghum.

Target Pests : Corn rootworm larvae (including species and strains resistant against other insecticides); alfalfa weevils; nematodes; rice water weevil; sugarcane borer; other soil and foliar insects.

Application : Soil treatment by ground equipment, usually in-furrow placement or banded over the row. Broadcast application of granules by ground or air. Foliar spray treatments by ground or air.

Rates of Application : 0.75 to 1.0 lb AI/acre; up to 5.0 lb AI/acre for certain uses; 0.5 lb AI/acre on rice.

Frequency : Soil application once per season. One or two foliar applications per season.

Time of Application : Soil applications at planting time in the spring. Foliar applications early to midsummer.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
6.0	None	1.0	5.0

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	0.1				0.1
SE	0.1				0.1
NC	4.4				4.4
SC	0.2				0.2
W	0.2				0.2
Totals	5.0	Negligible	Negligible	Negligible	5.0

The materials flow diagram for carbofuran is shown in Figure 12.

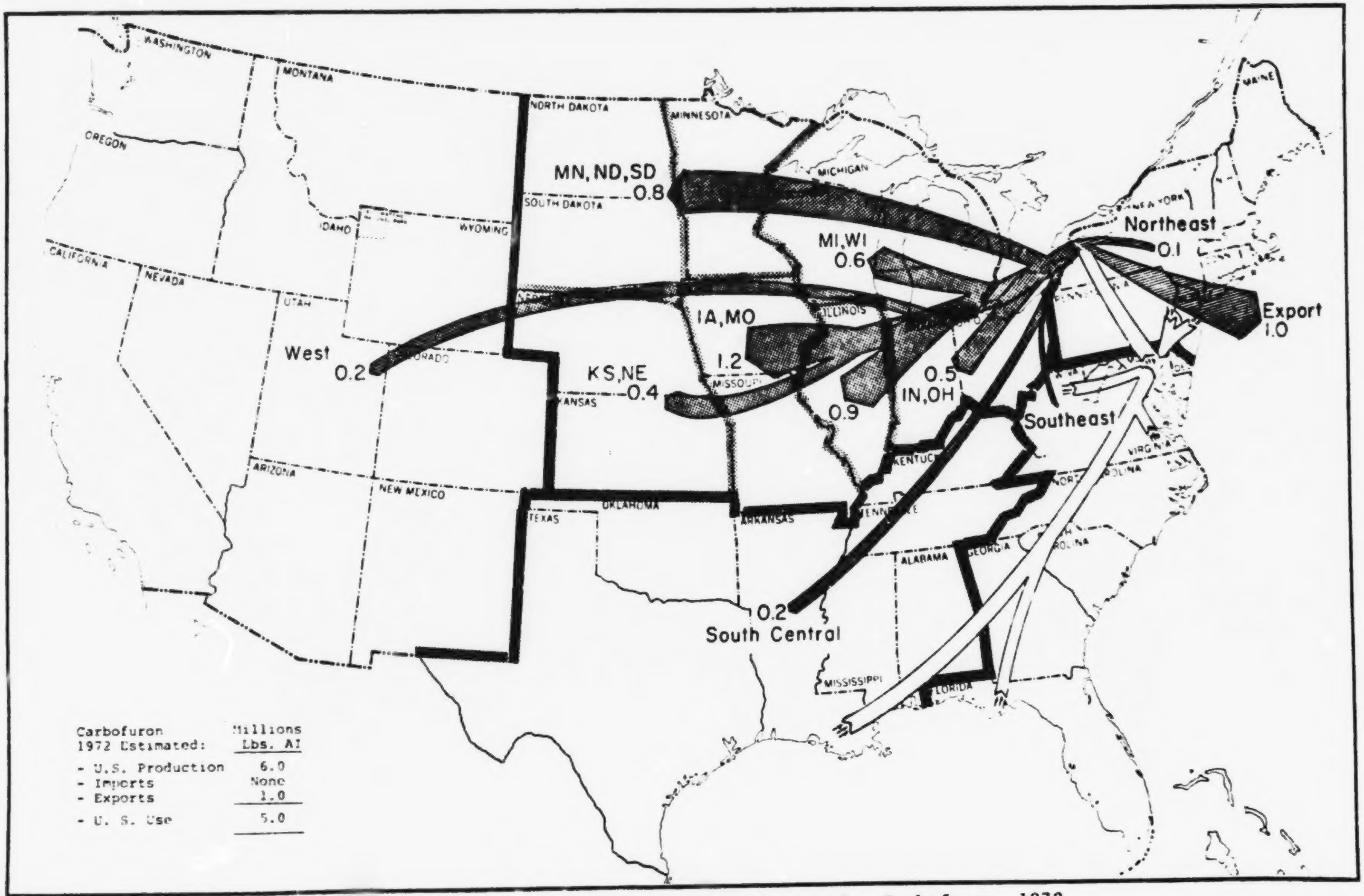
F. Alternatives

Chemicals : Other chemical insecticides including chlorinated hydrocarbons, organic phosphates and carbamates are available for control of corn rootworms and other soil pests. Carbofuran is the most effective insecticide currently available against resistant corn rootworms. It is also one of the most effective insecticides against alfalfa weevils and other insects against which it is recommended. Other chemical insecticides are available for the same control purposes.

Nonchemical : No effective, specific nonchemical methods have been developed as yet for the control of soil insects or nematodes affecting farm crops. Adjustment of crop rotation is an indirect measure.

G. Environmental Impact Potential

Mammalian Toxicity : In toxicity tests on laboratory mammals, carbofuran is highly toxic if applied orally. It is a direct inhibitor of cholinesterase. Topical applications to mucous membrane will elicit a localized effect without systemic intoxication. Small quantities in the eye cause constriction of the pupil. The 4 lb AI/gal flowable and the 75% wettable powder formulations of carbofuran require labeling as highly toxic pesticides, including the signal word "Danger - Poison" and skull and crossbones. The 10% and


MN, ND, SD
0.8
MI, WI
0.6
Northeast
0.1
Export
1.0
IA, MO
1.2
0.5
IN, OH
0.9
KS, NE
0.4
West
0.2
Southeast
0.2
South Central
WASHINGTON
OREGON
MONTANA
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
KANSAS
MISSOURI
OKLAHOMA
TEXAS
ARKANSAS
MICHIGAN
ILLINOIS
KENTUC
NEW YORK
MAINE
VIRGINIA
ALABAMA
GEORGIA
MISSISSIPPI
FLORIDA

Carbofuron 1972 Estimated:	Millions Lbs. AI
- U.S. Production	6.0
- Imports	None
- Exports	1.0
- U. S. Use	5.0

Figure 12 - Materials Flow Diagram for Carbofuran, 1972

lower concentrated granular formulations are classified as moderately toxic and require the signal word "Warning."

In chronic toxicity tests, the following no-effect levels in the diets of the animals were established: 25 ppm on rats over 2 years; 20 ppm on dogs over 2 years; 10 ppm on rats over 3 generations; 50 ppm on dogs over one generation. Tolerances for residues of carbofuran have been established for a number of crops, ranging from 0.02 ppm (milk) to 20 ppm (alfalfa hay), 0.1 ppm for corn grain.

Nontarget Organisms : Carbofuran is toxic to fishes, birds, wild mammals and to the soil fauna. It is only slightly toxic or relatively nontoxic to other soil organisms. There are no data on its toxicity to lower aquatic organisms. Laboratory model ecosystem studies indicate that carbofuran is readily biodegradable and does not build up in food chains.

Carbofuran is highly toxic to bees and to beneficial insects (parasites and predators) on direct contact. This is a potential problem mainly with foliar applications.

Environment : The behavior and persistence of carbofuran in the environment have been studied quite extensively. Carbofuran is moderately persistent in the soil. Its half-life in treated soil is of the order of 1-2 months. Residues generally decline to 10% or less of the applied rate in a single growing season. Carbofuran does not volatilize appreciably from treated areas. There may be some leaching in light soils, little if any in heavy soils. If heavy rainfall follows soon (within 1 to 2 weeks) after foliar or soil applications, there may be substantial run-off from target areas. In a lysimeter study, carbofuran residues in run-off water were 20 to 30 times higher than residues in the sediment. Carbofuran is degradable by biological organisms and by nonbiological factors. Some metabolites have been identified.

Evaluation : Carbofuran formulations are highly or moderately toxic, depending upon the concentration of active ingredient. Aside from the operator hazards inherent in products of high acute mammalian toxicity, there are no indications of other serious hazards to human health from the use of carbofuran in accordance with label directions.

Carbofuran has a broad spectrum of biological effectiveness. Carbofuran residues may be transported away from target sites by surface run-off or, in the case of light soils, leaching. This is likely to occur only if heavy rainfalls follow soon after application. In such circumstances, terrestrial or aquatic ecosystems in the vicinity of target areas may be adversely affected.

CASE STUDY NO. 4. CHLORDANE

A. Production Description

Chemical Name: Mixture of Octachloro-4,7-methanotetrahydroindane and Related Compounds

Trade Names: Belt, Chlordan, Chlor Kil, Corodane, Kypchlor, Octachlor, Ortho-Klor, Synklor, Topiclor 20, Velsicol 1068

Pesticide Class: Broad spectrum insecticide; Chlorinated hydrocarbon

Properties: Solid, insoluble in water; moderately toxic

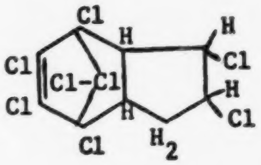
B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated Annual Production
Velsicol	Marshall, Illinois	30 million lb (estimated)	20 million lb

C. Production Methods and Waste Control Technology

Information on the production and waste control technology for chlordane have been reported.[1] The process reactions are approximately as follows:

$$\text{Naphtha} \longrightarrow \text{Cyclopentadiene } (C_5H_6)$$
$$Cl_2 + \text{NaOH (aq.)} \longrightarrow \text{NaClO (aq.)}$$
$$\text{NaClO (aq.)} + C_5H_6 \longrightarrow C_5Cl_6 + \text{NaCl (alk. solu.)}$$
$$C_5Cl_6 + C_5H_6 \longrightarrow \text{Chlordene } (C_{10}H_6Cl_6)$$
$$\text{Chlordene} + Cl_2 \longrightarrow \text{Tech. chlordane } (C_{10}H_6Cl_8 + \text{related cpds.})$$



A production and waste schematic are shown in Figure 13.

Spent hypochlorite wastewater is about 2% NaOH and 400 ppm C_5Cl_6. The production and handling area is diked with runoff and process water going to deep well disposal on the plant site. Tank cars are leased, dedicated to chlordane, and if cleaned, the washings go to deep wells.

Chlordane is made by a continuous process. Velsicol receives raw products for its production by pipeline and tank cars.

D. Formulation, Packaging, and Distribution

Most of the chlordane is sold in the technical grade to independent formulators and is shipped in tanks, 30-gal. and 5-gal. drums by rail and truck. Chlordane is available in the following formulations: 4 lb/gal. and 8 lb/gal. emulsifiable concentrates; 2 and 20% oil solutions; 10, 6, and 5% dusts; 33-1/3, 25, 20, 10, and 5% granules; and 25 and 40% wettable powders.

E. Use Patterns

General :	Technical chlordane consists of a heavily chlorinated mixture of isomers. It was the first cyclodiene chemical to be developed for insect control and has been in commercial use for more than 20 years. It is a versatile, broad-spectrum insecticide. Its use volume has recently experienced a renewed increase. Analytical techniques for chlordane are not as refined in regard to specificity and sensitivity as for some other pesticides. It is therefore difficult to make sweeping comparisons, but it is claimed that chlordane residues are somewhat less persistent in the environment than those of, for instance,DDT, aldrin or dieldrin. Nonagricultural uses accounted for an estimated 80% of total U.S. consumption of chlordane in 1972.
Action :	Broad-spectrum insecticide; contact, inhalation and stomach poison. Stimulates the central nervous system. Exact mode of action not known. No systemic action on plants.
Target Crops :	Corn; potatoes; protection of structures; lawn and turf; many other field, vegetable and fruit crops; ornamentals, shade trees; livestock.

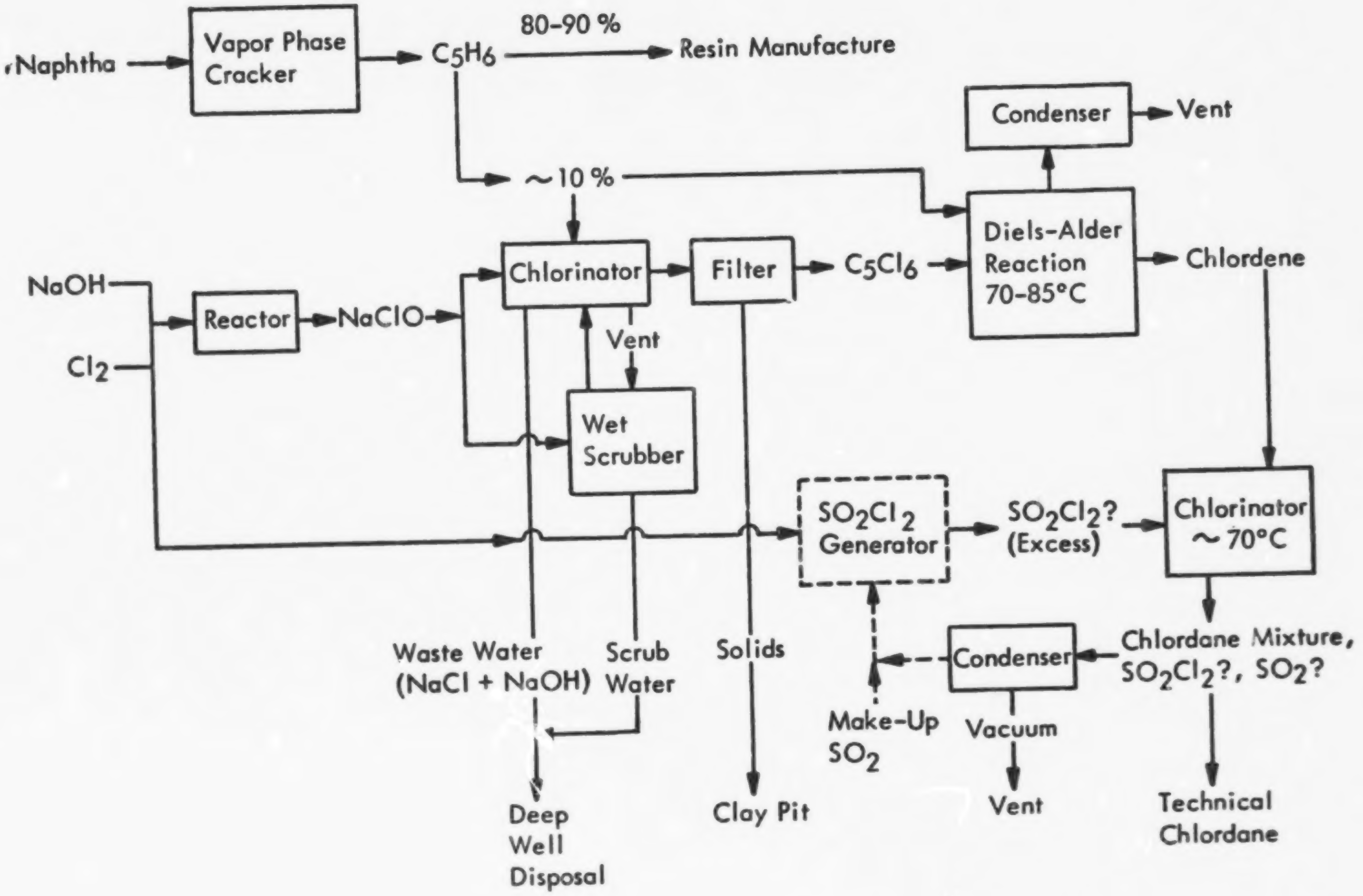

Naphtha
Vapor Phase Cracker
C_5H_6
80-90 %
Resin Manufacture
~10 %
NaOH
Cl_2
Reactor
NaClO
Chlorinator
Vent
Wet Scrubber
Filter
C_5Cl_6
Diels-Alder Reaction 70-85°C
Condenser
Vent
Chlordene
SO_2Cl_2 Generator
SO_2Cl_2? (Excess)
Chlorinator ~70°C
Chlordane Mixture, SO_2Cl_2?, SO_2?
Condenser
Vacuum
Vent
Make-Up SO_2
Technical Chlordane
Waste Water (NaCl + NaOH)
Scrub Water
Solids
Deep Well Disposal
Clay Pit

Figure 13 - Production and Waste Schematic for Chlordane[1]

Target Pests : White grubs, cutworms, wireworms, Japanese beetle larvae, other beetle larvae, other soil insects; termites; grasshoppers; ants; some foliar insects; household insects, stored products insects, livestock insects. Resistance of target insects in some areas.

Application : Soil treatment (most important); some foliar applications; baits; seed treatment (small); indoor spray applications. Soil applications by ground equipment, predominantly broadcast. Livestock dips or sprays.

Rate of Application : Soil treatment: 2-5 lb AI/acre, up to 10 lb AI/acre for some uses.
Seed treatment: 2 oz AI/bushel seed.
Foliar treatment: 1-3 lb AI/acre or 1 lb AI/100 gal.
Termite control: 1% AI in water or oil.
Bait: 1 lb AI/acre.
Indoor applications: 2-3% AI sprays, 5-6% AI dusts.
Use on animals: 2-4 lb AI/100 gal.

Frequency : Against soil insects on crops: One application per season.
Other uses: one or more treatments per year, as required.

Time of Application : Agricultural uses: Mostly spring at planting time. Use against termites, lawn, garden and household insects year-round in the South, during warmer months of the year in the North. Against animals insects: Throughout the year as required.

Estimated Distribution : (All figures in millions of pounds AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
20	None	5	15

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies[a]	Sub-Totals	Home and[b] Garden	Totals
NE	0.7	1.0		1.7		
SE	0.3	1.3		1.8		
NC	1.7	1.6		3.4		
SC	0.1	1.3		1.6		
NW	0.1	0.3		0.4		
SW	0.1	1.0		1.1		
Totals	3.0	6.5	0.5	10.0	5.0	15.0

---

[a] Too small to break out, included in subtotals.

[b] Geographic distribution not known.

The materials flow diagram for chlordane is shown in Figure 14.

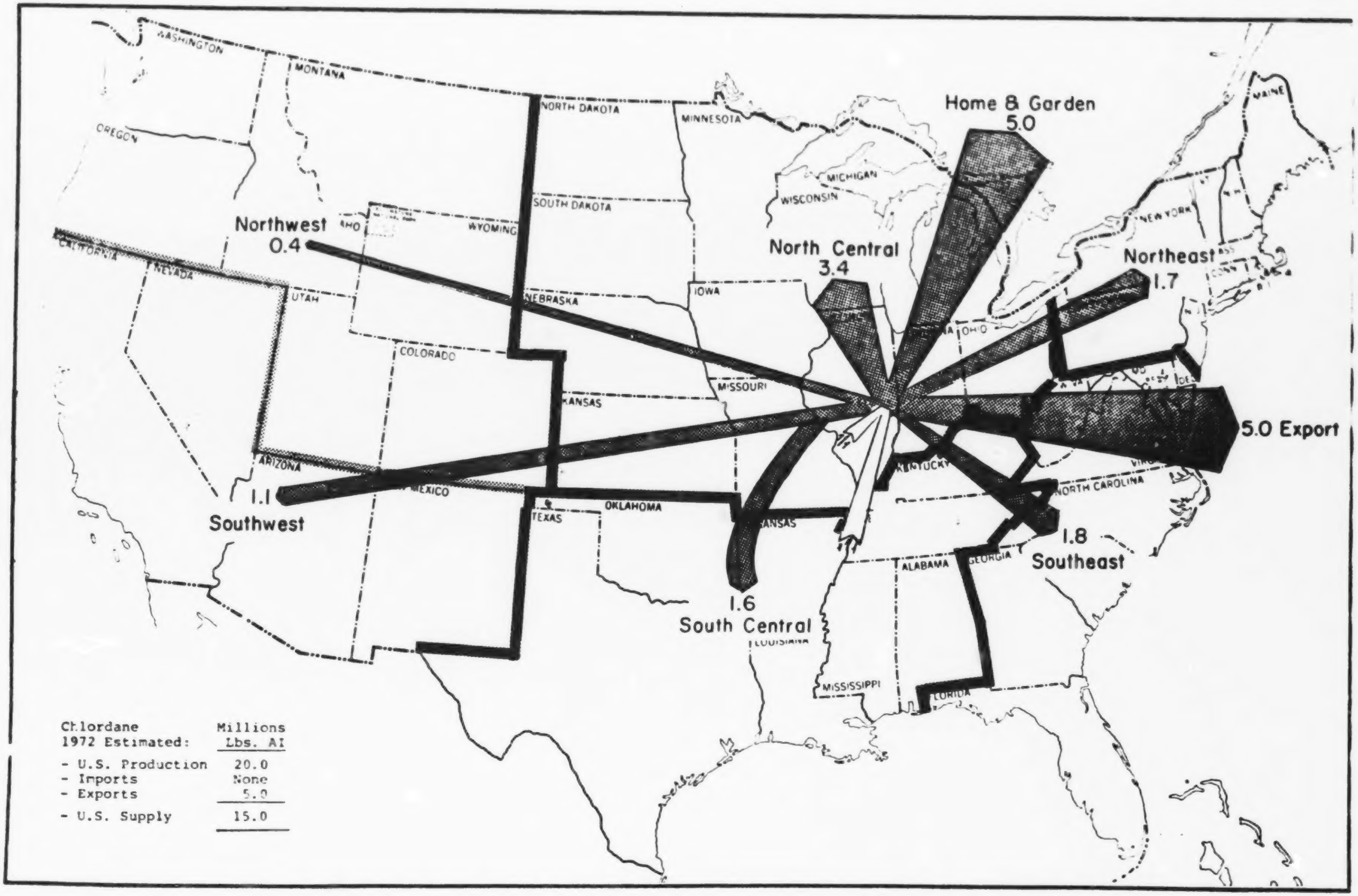
F. Alternatives

Chemicals : Against soil inspects; other chlorinated hydrocarbon insecticides, especially aldrin, dieldrin and heptachlor (these are also effective against termites); furthermore, carbofuran, phorate and several other carbamate and organic phosphate insecticides. These latter products are effective against some soil insects, but have a narrower spectrum of effectiveness, are more expensive, and are not satisfactory for termite control.

Against lawn and turf insects; other chlorinated hydrocarbon Insecticides, many organic phosphate and carbamate insecticides.

Against household insects; other chlorinated hydrocarbon, organic phosphate and carbamate insecticides.

Nonchemical : No effective nonchemical methods of control of soil insects affecting farm crops have been developed to date. Adjustment of crop rotation is an indirect measure to reduce soil insect damage.


Home & Garden
5.0
Northwest
0.4
North Central
3.4
Northeast
1.7
5.0 Export
1.1
Southwest
1.6
South Central
1.8
Southeast
WASHINGTON
MONTANA
OREGON
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
WISCONSIN
MICHIGAN
NEW YORK
MAINE
CALIFORNIA
NEVADA
UTAH
NEBRASKA
IOWA
OHIO
COLORADO
KANSAS
MISSOURI
KENTUCKY
ARIZONA
MEXICO
OKLAHOMA
TEXAS
NORTH CAROLINA
ALABAMA
GEORGIA
LOUISIANA
MISSISSIPPI
FLORIDA

Chlordane 1972 Estimated:	Millions Lbs. AI
- U.S. Production	20.0
- Imports	None
- Exports	5.0
- U.S. Supply	15.0

Figure 14 - Materials Flow Diagram for Chlordane, 1972

Parasites and diseases are known to affect some lawn and turf soil insects, especially the Japanese beetle. To this date, no systems have been developed for the general use of these biological agents for the control of lawn and turf insects.

There are no effective nonchemical methods for the control of termites.

Good housekeeping and sanitation will reduce household insect problems, but may not solve them completely.

G. Environmental Impact Potential

Mammalian Toxicity : Chlordane is moderately toxic to laboratory animals in acute toxicity tests via the oral, dermal and inhalation routes. It is moderately irritating to the eyes, and slightly irritating to the skin and the respiratory tract. Emulsifiable concentrate formulations of chlordane require the signal word "Warning" on the label. Granular and dust formulations of lower concentration require the signal word "Caution". Prolonged exposure to subacute concentrations of chlordane may produce increasingly severe toxic effects.

In chronic toxicity tests, the no-effect level in the diet of laboratory animals was between 3 and 15 ppm. Tolerances for residues of chlordane have been established for a large number of commodities, all at 0.3 ppm.

Nontarget Organisms : Chlordane is highly toxic to fishes and lower aquatic organisms. It is slightly toxic to birds, moderately toxic to wild mammals, highly toxic to soil insects, and moderately toxic to some soil bacteria and to earthworms. Chlordane is highly toxic to bees and to beneficial insects (parasites and predators) on direct contact, but this does not take place in its predominant uses where it is applied to the soil or indoors.

Chlordane bioaccumulates in oysters. There are no data on its build-up in food chains.

Environment : Chlordane is a persistent chlorinated hydrocarbon insecticide. It persists in the soil for more than one year, sometimes for many years. Chlordane residues are carried over to the following season. Chlordane may volatilize to some extent from surfaces exposed to atmospheric conditions. Its propensity for leaching from treated soil is low. It may migrate from treated areas adsorbed on soil solids by erosion and sediment transport. Chlordane is degradable by biological organisms and by nonbiological factors. Its overall rate of degradation is slow. Degradation is believed to result eventually in hydrophilic products such as chlorohydrin and glycols, but the exact pathways are not known.

Evaluation : Chlordane formulations do not present peculiar operator hazards. There are no reports of other serious direct hazards to human health from the use of chlordane in accordance with label directions.

Chlordane products are relatively inexpensive to the user. Thus, there are no strong economic restraints against unnecessary use or overuse.

In view of the persistence and broad spectrum of biological efficacy of chlordane, the U. S. Department of Health, Education and Welfare Secretary's Commission on Pesticides and their Relationship to Environmental Health has recommended that its usage (and that of a number of other pesticides of similar properties) be restricted to specific, essential uses which create no known hazard to human health or to the quality of the environment.

CASE STUDY NO. 5. DIAZINON

A. Product Description

Chemical Name: 0,0-Diethyl-0-(2-isopropyl-4-methyl-6-pyrimidinyl)phosphorothioate

Trade Names: G-24480, Basudin, Diazajet, Diazide, Diazol, Dazzel, Gardentox, Spectracide

Pesticide Class: Insecticide; organophosphate

Properties: Amber liquid; B.P., 83-84°C at 0.002mm Hg (89°C at 0.1 mm)

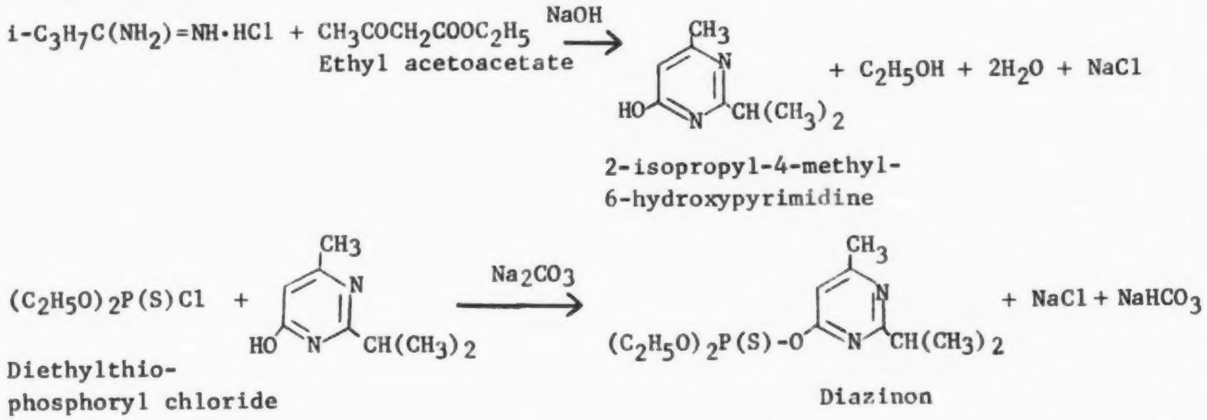
B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated Annual Production
Ciba-Geigy Corporation	McIntosh, Alabama	15 million lb (estimated)	12 million lb

C. Production Methods and Waste Control Technology

The reaction chemistry for the production of diazinon is believed (based on a visit with Geigy personnel) to be as follows:

$$\underset{\text{iso-Butyronitrile}}{i\text{-}C_3H_7CN} + \underset{\text{Methanol}}{CH_3OH} \xrightarrow{HCl} \underset{\text{methyl imidoisobutyrate hydrochloride}}{i\text{-}C_3H_7C(OCH_3){=}NH \cdot HCl} \xrightarrow{NH_3} \underset{\text{isobutyramidine hydrochloride}}{i\text{-}C_3H_7C(NH_2){=}NH \cdot HCl} + CH_3OH$$



i-C3H7C(NH2)=NH·HCl + CH3COCH2COOC2H5
Ethyl acetoacetate
NaOH
CH3
N
HO
N
CH(CH3)2
+ C2H5OH + 2H2O + NaCl
2-isopropyl-4-methyl-6-hydroxypyrimidine
(C2H5O)2P(S)Cl
Diethylthiophosphoryl chloride
Na2CO3
(C2H5O)2P(S)-O
+ NaCl + NaHCO3
Diazinon

A tentative production and waste schematic for diazinon is shown in Figure 15.

C. Production and Waste Control Technology

Ciba-Geigy purchases most of the raw materials for diazinon production. There are a number of sources for isobutyronitrile including Air Products (Pace, Florida); Union Carbide (Institute, West Virginia); Eastman (Kingsport, Tennessee) and possibly others. The alcohols are obtained mainly from Gulf Coast sources. Ammonia is obtained principally from Louisiana (Donaldsonville, Geismar), some quantities are obtained internally. Acetoacetic ester is purchased from Union Carbide, Eastman, and possibly others. These chemicals are received by bulk transport principally by tank cars but some by tank trucks. Large storage facilities are available at the Alabama plant to hold supplies.

In the first step of their production process, isobutyronitrile is reacted with methanol and HCl to produce the corresponding imido ester hydrochloride. There are no by-products to this reaction except excess hydrochloric acid which is recycled. In this reaction, the alcohol acts as a shielding agent.

In the second step, the ester is treated with ammonia to form the corresponding amidine. There are also no by-products to this step; the methyl alcohol is recovered by distillation and recycled.

The next step is the most critical and most difficult step in the production of diazinon. The amidine is condensed with acetoacetic ester in a reaction which is very sensitive to control. It is relatively easy to obtain 70% yields, but, in order for the process to be economically successful, 95% yields must be obtained. The resulting pyrimidine is insoluble in the reaction mixture (the sodium salt, however, is very soluble) and it is separated along with small amounts of other insoluble inorganic compounds (this separation does not generate filter solids which would require disposal). The aqueous stream plus alcohols and other organic products (including acetone) are subjected to a stripping process in which pure materials are separated and recycled. The residual aqueous solution is transferred to a biological sewage treatment plant and the residual materials from this process are incinerated. The pyrimidine product is subjected to a drying step.

The next step is the reaction of the pyrimidine with diethylthiophosphoryl chloride. Ciba-Geigy purchases the chlorinated phosphate ester and therefore do not have waste treatment facilities for sulfide and phosphorus wastes. The manufacture of this ester causes the most notorious waste treatment problems in the production of phosphorus-sulfur pesticides

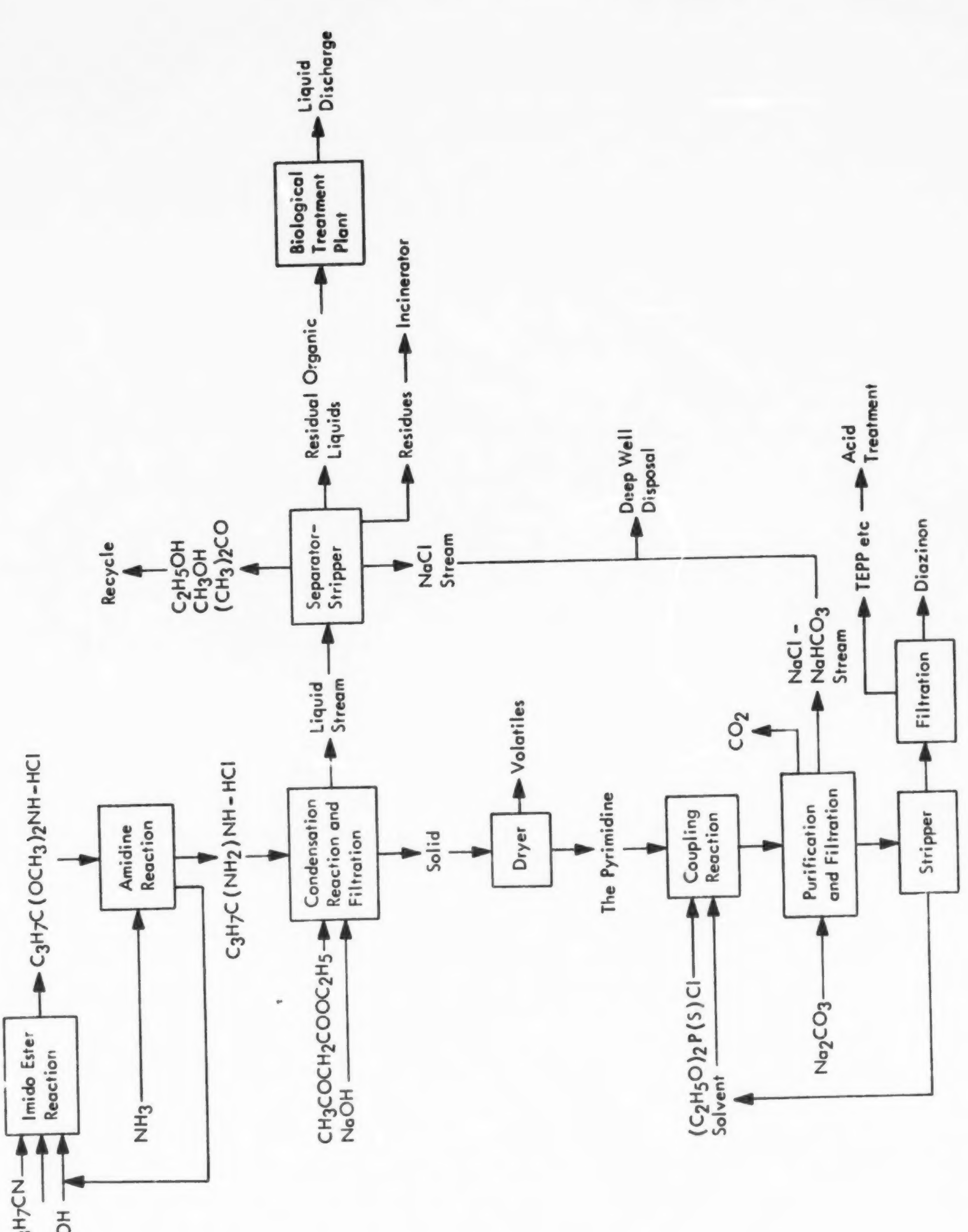

i-C3H7CN
HCl
CH3OH
Imido Ester Reaction
C3H7C(OCH3)2NH-HCl
NH3
Amidine Reaction
C3H7C(NH2)NH-HCl
CH3COCH2COOC2H5
NaOH
Condensation Reaction and Filtration
Liquid Stream
Separator-Stripper
Recycle
C2H5OH
CH3OH
(CH3)2CO
Residual Organic Liquids
Biological Treatment Plant
Liquid Discharge
Residues
Incinerator
NaCl Stream
Deep Well Disposal
Solid
Dryer
Volatiles
The Pyrimidine
(C2H5O)2P(S)Cl
Solvent
Coupling Reaction
Na2CO3
Purification and Filtration
CO2
NaCl - NaHCO3 Stream
Stripper
Filtration
TEPP etc
Acid Treatment
Diazinon

Figure 15 - Production and Waste Schematic for Diazinon

of this kind. The reaction is reported to proceed in 85% yield. There are toxic by-products formed during this reaction. These are the combined ester related to TEPP. Some of the TEPP by-products contain sulfur. These materials are removed from the reaction mixture, evidently by a filtration step, and are decontaminated by a treatment with acid. The reaction mixture is treated with sodium carbonate. The resulting product is sodium bicarbonate, which, along with sodium chloride, is also removed in the filtration step. The filtration step results in the removal of a haze which is formed in the brown reaction mixture. It is believed that the brown material in the diazinon solution is a sulfur polymer. Diazinon itself is water white and almost odorless.

Ciba-Geigy has made adaptation in the production of four pesticides at McIntosh. Recycling of by-products was necessary in order to meet environmental standards. They have found that the recovery of the by-products actually pays for the required adaptations.

There is no air pollution problem in the production of diazinon. However, carbon dioxide is evolved during the primidine-phosphoryl chloride operation (caused by the addtion of sodium carbonate to the acidic reaction mixture). The equipment is dedicated and can be run either continuously or batch-wise.

D. Formulation, Packaging, and Distribution

Ciba-Geigy makes the following formulations: a 50% wettable powder and a 50% dust, several types of 4 lb/gal. emulsifiable concentrates, a 14.3% granular, 2% dust and 2% granular, and an 8 lb/gal. (85-90% AI) sold to Pest Control Operators and agricultural formulators. The liquid concentrate of the formulations are shipped from McIntosh in bulk in 5- and 55-gal. drums and 1-gal. F-style cans. Exports are shipped in 55-gal. drums.

Ciba-Geigy estimated usage breakdown as follows: one-third - agriculture, one-third - pest control, one-third - garden uses. Agricultural usage is primarily in California, Arizona, South Texas, Florida, and New Jersey. The largest PCO use is in the "southern cockroach belt." Diazinon is also very effective against lawn insects affecting southern grasses.

The proportions of production that is exported has been estimated as high as 50%. Some of this is sent to Switzerland as technical, and then formulated there. In addition, some of the 4 lb/gal. formulation is exported on AID programs to Pakistan, Vietnam, Bagladesh, and other countries. No sizable quantities of diazinon are imported, although it is also produced in Japan and Israel and by other countries. Most of Ciba-Geigy's worldwide diazinon requirements are fulfilled by their Alabama plant.

E. Use Patterns

General : Diazinon has been commercially available for almost 20 years. It is a versatile insecticide that controls a wide variety of foliar and soil insects and some species of nematodes on agricultural crops, lawns, turf, and ornamentals, plus a number of insects affecting man and animals. It is classified as "moderately toxic" to mammals, and it is not persistent in the environment.

About 40% of the estimated U.S. consumption of diazinon in 1972 was used for agricultural purposes.

Action : Broad-spectrum insecticide; contact, stomach and inhalation action; inhibits cholinesterase and stimulates the nervous system.

Target Crops : Corn, alfalfa, other field and forage crops; vegetable, fruit and nut crops; lawn and turf; ornamentals; homes, buildings, premises, other indoor areas; livestock.

Target Pests : Many foliar and soil insects, some nematodes; cockroaches and other indoor pests; livestock ectoparasites. Controls some insects, especially soil insects and household insects, that have become resistant to chlorinated hydrocarbon insecticides. Other insects, including houseflies and certain livestock insects, have developed resistance to diazinon in some areas.

Application : Foliar spray applications by ground or air equipment. Soil applications and applications to lawn and turf by ground equipment. Seed treatment (planter box). Indoor applications by spray equipment.

Rates of Application : 0.25-1 lb AI/acre, or 0.25-1.5 lb AI/100 gal. for most foliar treatments (higher rates for some); 1-4 lb AI/acre, up to 10 lb AI/acre for soil treatments, 0.5-1 oz AI/bu for planter-box seed treatments; 0.5-1% for indoor pests.

Frequency : 1 to 6-8 applications per season or per year.

Time of Application : On annual crops, from planting time throughout the growing season. On perennial plantings and for other uses, throughout the year as required.

Estimated Distribution : (All figures in millions of lb AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
12	None	5	7

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Subtotals	Home and Garden[a]	Totals
NE	0.1	0.2	0.1	0.4		
SE	0.3	0.3	0.2	0.8		
NC	1.8	0.2	0.1	2.1		
SC	--	0.3	0.3	0.6		
W	0.8	0.2	0.1	1.1		
Totals	3.0	1.2	0.8[b]	5.0	2.0	7.0

---

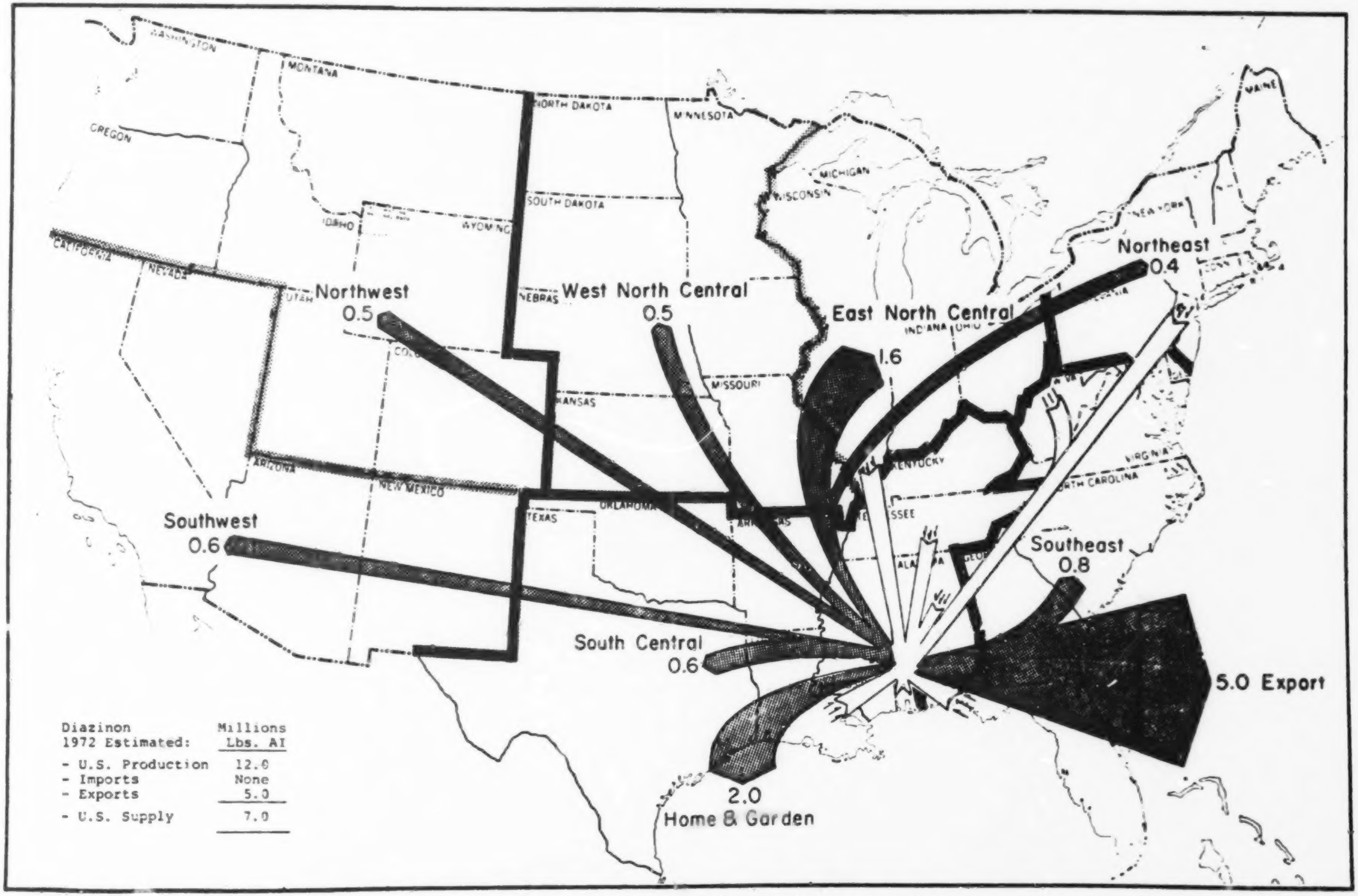
[a] Geographic distribution not known.

[b] This quantity uncorrected for an apparent error in data for usage by federal government agencies. Governmental use may be as high as 1.6 million pounds (see Table XXII).

The materials flow diagram for diazinon is shown in Figure 16.

F. Alternatives

Chemicals : A number of other organic phosphate and carbamate insecticides (including malathion, fenthion, chlorpyrifos, carbaryl, propoxur, and others) are available for control of the insects against which diazinon is used. Some chlorinated hydrocarbon insecticides are also used for some of the same control purposes. No other single current insecticide has the same combination of physical, chemical, biological and economic properties as diazinon, but a number of other insecticides are available for each of the major uses of diazinon.


Northwest
0.5
West North Central
0.5
East North Central
1.6
Northeast
0.4
Southeast
0.8
5.0 Export
South Central
0.6
Southwest
0.6
2.0
Home & Garden
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRAS
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
MISSOURI
ARKANSAS
WISCONSIN
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
ALA
GEO
NORTH CAROLINA
VIRGINIA
NEW YORK
MAINE

Diazinon 1972 Estimated:	Millions Lbs. AI
- U.S. Production	12.0
- Imports	None
- Exports	5.0
- U.S. Supply	7.0

Figure 16 - Materials Flow Diagram for Diazinon

Nonchemical : Biological control agents and integrated pest management methods are being developed for control of some of the foliar insects controlled by diazinon, especially on fruit and vegetable crops. No specific, nonchemical methods are currently available for control of many of the remaining insect pests against which it is used. This applies particularly to soil insects, nematodes, and household and livestock insects. Good farming practices, sanitation and housekeeping often are only partial remedies against such pests.

G. Environmental Impact Potential

Mammalian Toxicity : In acute toxicity tests on laboratory animals, diazinon was moderately toxic via the oral, dermal and inhalation routes. It is moderately to severely irritating to the eyes, moderately to mildly irritating to the respiratory tract and the skin. Most of the formulations of diazinon require the signal word "Warning" on the label.

In chronic toxicity tests, there were no gross effects in rats fed 100 ppm in the diet for 2 years, nor in dogs fed 4.3 - 5.2 mg/kg of body weight/day for 43 weeks. In both rats and dogs, there was cholinesterase inhibition at these dosage rates. No malformations or adverse effects on reproduction were seen in a 3-generation study on rats. In monkeys, 5.0 mg/kg of body weight per day administered for 106 weeks caused no effects other than cholinesterase inhibition. Tolerances for residues of diazinon have been established for many crops, ranging from 0.01 - 60 ppm, 0.75 ppm for most fruits and vegetables.

Nontarget Organisms : Diazinon is highly toxic to fishes, lower aquatic organisms, birds, and soil insects; slightly toxic to wild mammals; and relatively nontoxic to soil organisms other than insects. There are no data on its possible build-up in food chains. Diazinon is highly toxic to honeybees and to other beneficial insects (predators and parasites).

Environment : Diazinon is moderately persistent in the environment. Residual insecticidal effectiveness persists for about 7 to 10 days on foliage; for 4 to 6 weeks on indoor inert surfaces; and for 2 to 4 months in soils. The half-life of diazinon residues in the soil is about 4 to 6 weeks. Generally, less than 10% of an applied rate persists in the soil for more than 6 months, and residues decline completely in a single growing season. Diazinon may dissipate from treated areas by volatilization. Leaching from treated soils may also occur, based on laboratory studies. Migration of diazinon residues from treated areas in surface run-off in water or on sediments is also possible. Diazinon is degradable by biological organisms and by nonbiological factors. Studies in which the persistence of diazinon in autoclaved and nonautoclaved silt loam was compared at different temperatures, moisture levels and pH levels indicate that nonbiological degradative mechanisms predominate. The primary pathway of degradation of diazinon in the soil is hydrolysis at the heterocyclic phosphate bond, followed by rupture of the aromatic structure and eventual formation of CO_2.

Evaluation : Most diazinon formulations are moderately toxic and do not present peculiar hazards to persons handling them if used in accordance with the label directions. There are no indications of other serious hazards to human health from the proper use of diazinon as an insecticide.

Diazinon has a broad spectrum of biological effectiveness. Its residues may migrate from target sites by volatilization, leaching, or surface run-off. However, since diazinon is not highly persistent in the environment, terrestrial and/or aquatic ecosystems away from target areas are not likely to be adversely affected, except if heavy rainfalls follow soon after foliar or soil applications. Such effects, if they do occur, are likely to be only transitory.

CASE STUDY NO. 6. DISULFOTON

A. Product Description

Chemical Name: 0-0-Diethyl-S-[2-(ethylthio)-ethyl]phosphorodithioate

Trade Names: Bay 19639, Di-Syston, dithiodemeton, dithiosystox, Frumin Al, Solvirex

Pesticide Class: Systemic insecticide; organophosphate

Properties: Liquid of low volatility; insoluble in water; highly toxic; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Chemagro	Kansas City, Missouri	7 million pounds (estimated)	5 million pounds

C. Production Methods and Waste Control Technology

Information on production and waste control technology for disulfoton have been reported.[1] The reaction chemistry is:

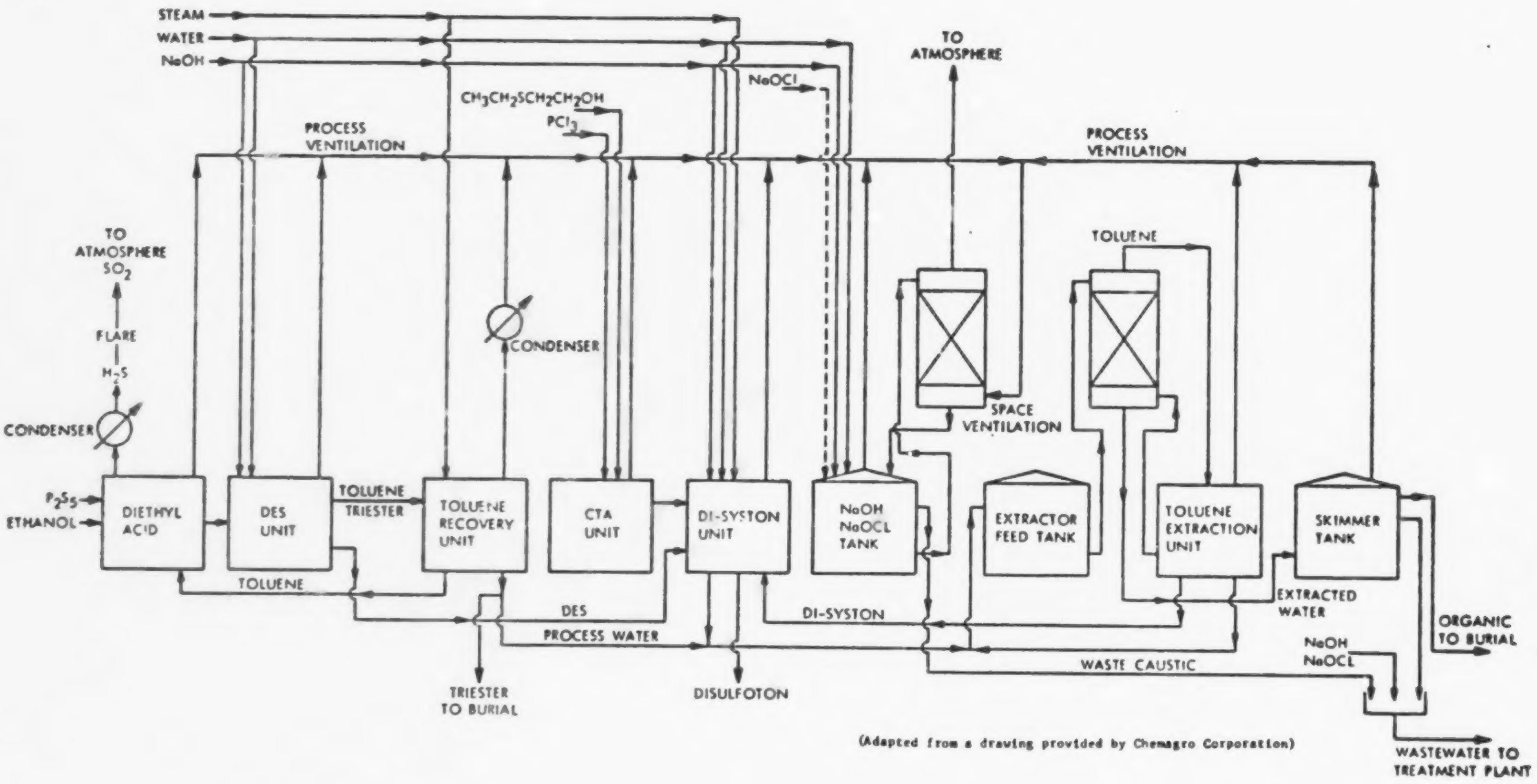
$$P_2S_5 + 4C_2H_5OH + 2NaOH \xrightarrow{\text{Toluene}} \underset{\text{"Diethyl Salt" (DES)}}{2(C_2H_5O)_2P(S)SNa} + H_2S + 2H_2O$$

$$PCl_3 + \underset{\text{"Thio Alcohol"}}{3HOC_2H_4\text{-}S\text{-}C_2H_5} \longrightarrow \underset{\text{"Chloro Thio Alcohol" (CTA)}}{3ClC_2H_4\text{-}S\text{-}C_2H_5} + P(OH)_3$$

$$(C_2H_5O)_2P(S)SNa + ClC_2H_4\text{-}S\text{-}C_2H_5 \longrightarrow \underset{\text{Disulfoton}}{(C_2H_5O)_2P(S)\text{-}S\text{-}C_2H_4\text{-}S\text{-}C_2H_5} + NaCl$$

A production and waste schematic is shown in Figure 17.

Caustic conditions (lime) remove some of the organophosphates during a retention period of 36 hr. The pH is also adjusted and polyelectrolyte flucculents added. The effluent is discharged into the Blue River with probably no more than parts-per-million range of any one


STEAM
WATER
NaOH
CH3CH2SCH2CH2OH
PCl3
NaOCl
TO ATMOSPHERE
PROCESS VENTILATION
PROCESS VENTILATION
TO ATMOSPHERE SO2
FLARE
H2S
CONDENSER
CONDENSER
TOLUENE
SPACE VENTILATION
P2S5
ETHANOL
DIETHYL ACID
DES UNIT
TOLUENE TRIESTER
TOLUENE RECOVERY UNIT
CTA UNIT
DI-SYSTON UNIT
NaOH NaOCL TANK
EXTRACTOR FEED TANK
TOLUENE EXTRACTION UNIT
SKIMMER TANK
TOLUENE
DES
DI-SYSTON
EXTRACTED WATER
PROCESS WATER
WASTE CAUSTIC
NaOH NaOCL
ORGANIC TO BURIAL
TRIESTER TO BURIAL
DISULFOTON
WASTEWATER TO TREATMENT PLANT

(Adapted from a drawing provided by Chemagro Corporation)

Figure 17 - Production and Waste Schematic for Disulfoton1/

pesticide. The solid wastes go to a landfill. The process filter cake is decontaminated then buried. The solid formulation line is covered by a dust collection system which has a baghouse backed with a venturi-type wet scrubber. The formulation equipment is cleaned by a solvent flush (which is used in the next batch), then by steam and water.

Chemagro produces disulfoton in a semicontinuous process in dedicated equipment. The process raw materials are received by rail and tank cars.

D. Formulation, Packaging, and Distribution

Disulfoton is formulated by Chemagro as follows: Di-syston® technical; 68% concentrate; 95% seed treatment; 6 lb/gal. emulsifiable concentrate; 10 and 15% granular; and two Di-syston®--Dasanit® combinations; 7.5% each insecticide granular, and 3 lb AI/gal. of each. Chemagro ships their technical product in 55-gal. drums, their 6 lb/gal. emulsifiable concentrate in 1-, 30-, and 55-gal. drums, the 70% deodorized form in 55-gal. drums, and the granular forms in 55-gal. steel drums, all primarily by truck.

E. Use Patterns

General : Disulfoton is a systemic insecticide, i.e., it is absorbed and translocated by treated plants. It controls primarily sucking insects, especially aphids and plant-feeding mites. Disulfoton active ingredient is an extremely toxic chemical.

Disulfoton was developed in the 1950's and has been in commercial use for about 15 years. Agricultural uses account for almost all of the estimated U.S. consumption in 1972. Small quantities are used on ornamentals in the home and garden market in the form of dry granules of very low AI content.

Action : Systemic insecticide; contact, stomach and inhalation poison, moderately broad spectrum. Strong cholinesterase inhibitor. Stimulates the nervous system.

Target Crops : Small grains, sorghum, corn, cotton, other field crops; some vegetable, fruit and nut crops; ornamentals.

Target Pests : Aphids, mites, thrips, leafhoppers, corn rootworms, flea beetles, several other insects.

Application : Foliar applications to commercial crops by air or ground equipment. Soil application to commerical crops by ground equipment. Seed treatment (by commercial seed treaters only). Application to ornamentals by low-concentration granules, fertilizer mixtures, or root feeder cartridges. Treatment of trees by injection or incorporation into the soil under the tree from base to drip-line.

Rates of Application : 0.25-1.0 lb AI/acre, up to 5.0 lb AI/acre for some uses. 0.25-0.5 lb AI/100 lb of seed.

Frequency : 1-3 applications per season.

Time of Application : Soil application at planting time. Foliar applications spring to mid-summer.

Estimated Distribution : (All figures in million of pounds AI per year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
5	None	Negligible	5

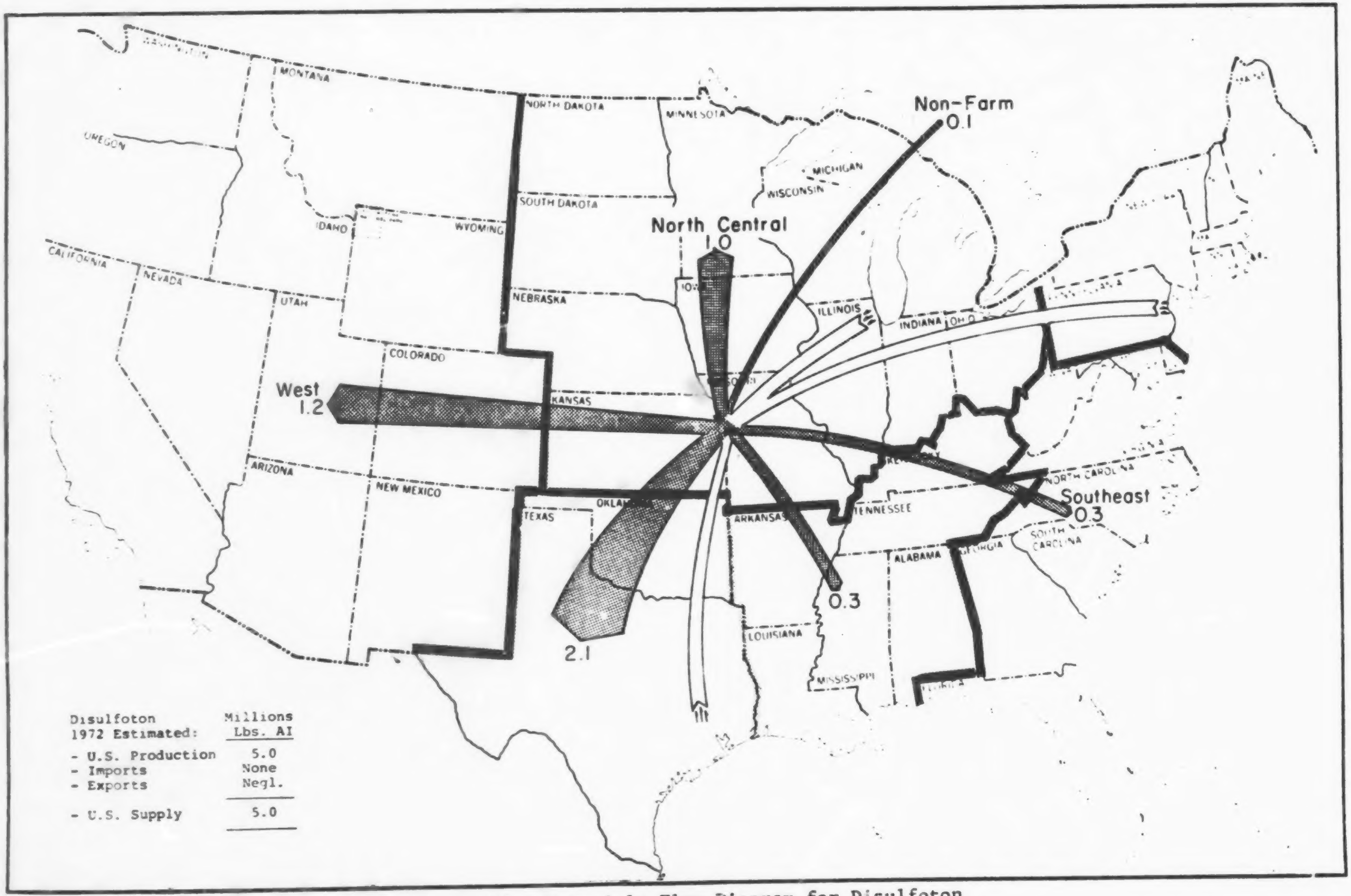
DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	Negligible			All Areas	0.02
SE	0.3				0.32
NC	1.0				1.02
SC	2.4				2.42
W	1.2				1.22
Totals	4.9	Negligible	Negligible	0.1	5.00

The materials flow diagram is shown in Figure 18.

F. Alternatives

Chemicals : Several other systemic organic phosphate insecticides are close chemical relatives of disulfoton and have a very similar spectrum of insecticidal effectiveness, including


Non-Farm
0.1
North Central
1.0
West
1.2
Southeast
0.3
0.3
2.1
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
TEXAS
MINNESOTA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
ARKANSAS
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
LOUISIANA
MISSISSIPPI

Disulfoton 1972 Estimated:	Millions Lbs. AI
- U.S. Production	5.0
- Imports	None
- Exports	Negl.
- U.S. Supply	5.0

Figure 18 - Materials Flow Diagram for Disulfoton

phorate, and demeton and demeton-methyl and their several analogs and homologs. Insects controlled by disulfoton are also controlled by a number of other systemic and nonsystemic insecticides.

Systemic insecticides such as disulfoton can be made more selective by the manner in which they are used. For instance, disulfoton applied to the soil will control sucking insects on plants, but will not destroy honeybees or other beneficial insects. Disulfoton (and other systemic insecticides that have similar properties) are therefore useful in some integrated pest management programs.

Nonchemical : Many of the insects controlled by disulfoton have naturally occurring predators and parasites that may suppress them. Biological control agents and integrated pest management methods are being developed and employed on some of the crops on which disulfoton is used.

G. Environmental Impact Potential

Mammalian Toxicity : Disulfoton is extremely toxic to laboratory animals by the oral and dermal routes, highly toxic by inhalation. It is not irritating to eyes, nose, throat or skin. However, only a few drops of disulfoton AI, or of the highly concentrated liquid formulations ingested by mouth, adsorbed through the skin, or splashed in the eye could be fatal to an adult human. Even smaller quantities may be fatal to children. Toxicity studies on laboratory animals indicate, and field experience confirms that granular formulations are considerably less toxic via the dermal and inhalation routes than the liquid forms of disulfoton. All formulations containing more than 2% AI require labeling as highly poisonous chemicals, including the signal words "Danger - Poison" and skull and crossbones.

In chronic toxicity tests, the no-effect level (including cholinesterase inhibition) in the diet was 2 ppm for rats, 1 ppm for dogs. Tolerances have been established for residues of disulfoton for a number of crops, ranging from 0.3 to 12.0 ppm, 0.75 ppm for most.

Nontarget Organisms : Disulfoton is highly toxic to fishes, lower aquatic organisms, birds, wild mammals, and to soil fauna. It is moderately toxic to other soil organisms. There are no data on its possible bioaccumulation or build-up in food chains. On theoretical grounds, biomagnification is unlikely.

Disulfoton is highly toxic to honeybees and to beneficial insects (predators and parasites) on direct contact. Under field conditions, this will occur only when disulfoton is sprayed on plants at the higher rates of application, but not from granular or soil applications.

Environment : Disulfoton is moderately persistent in the environment. Its half-life in the soil ranged from 40 to 100 days. There is little likelihood of carryover of toxic residues to the next season following soil applications, except after applications late in the season. No data are available on possible volatilization of disulfoton from treated surfaces. Migration away from treated areas by leaching and by surface run-off in water or on solids is possible, but not likely to occur under field conditions except when heavy rainfall follow soon after application.

Disulfoton is degradable by biological organisms and nonbiological factors, including alkaline hydrolysis. Metabolites include disulfoton sulfoxide and sulfone, and the sulfoxide and sulfone of the corresponding oxygen analog. Smaller amounts of diethyl phosphate, diethyl phosphorothioate, diethyl phosphorodithioate and inorganic phosphate have also been identified as degradation products.

Evaluation : Disulfoton technical and all formulations (except those containing less than 2% AI) are highly toxic and present operator hazards inherent in products of this order of toxicity. There are no indications of other serious hazards to human health from the use of disulfoton in accordance with label directions.

Due to its somewhat limited spectrum of biological effectiveness and its systemic properties, disulfoton can be used selectively, and as a supplement to natural regulants of insect populations. Disulfoton residues may be transported away from target sites by surface run-off or leaching, but this is not likely to occur under field conditions except if heavy rainfalls follow soon after application. In such circumstances, terrestrial or aquatic ecosystems in the vicinity of target areas may be adversely affected.

CASE STUDY NO. 7. MALATHION

A. Product Description

Chemical Name: 0-0-Dimethylphosphorodithioate of diethyl mercaptosuccinate

Trade Names: Cuthion, Emmatos, Emmatos Extra, Fyfanon, Karbofos, Kop-Thion, Kypfos, Malaspray, Malamar, MLT, Zithiol

Pesticide Class: Nonsystemic insecticide and acaricide; organophosphate

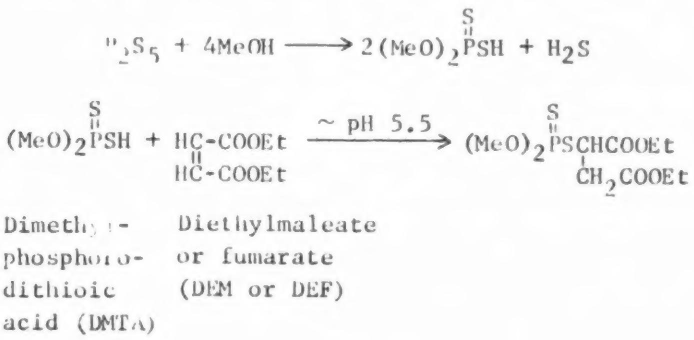
Properties: Liquid of low volatility; slightly soluble in water; low toxicity; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
American Cyanamid	Warners, New Jersey	35 million lb (estimated)	24 million lb

C. Production Methods and Waste Control Technology

Information on production methods and waste control technology for malathion have been reported.[1] The reaction chemistry is:



$$P_2S_5 + 4MeOH \longrightarrow 2(MeO)_2\overset{S}{\overset{\|}{P}}SH + H_2S$$

$$(MeO)_2\overset{S}{\overset{\|}{P}}SH + \begin{matrix} HC\text{-}COOEt \\ \| \\ HC\text{-}COOEt \end{matrix} \xrightarrow{\sim pH\ 5.5} (MeO)_2\overset{S}{\overset{\|}{P}}S\begin{matrix} CHCOOEt \\ | \\ CH_2COOEt \end{matrix}$$

Dimethyl-phosphorodithioic acid (DMTA)
Diethylmaleate or fumarate (DEM or DEF)

A production and waste schematic is shown in Figure 19.

The only by-product is H_2S, from which elemental sulfur is recovered in a Claus process unit. Some toluene is lost but the emission is not known. Wash water and liquid wastes (spills, etc.) go to a holding pond from which, in 1971, they were barging 150-200 miles to sea. Equipment

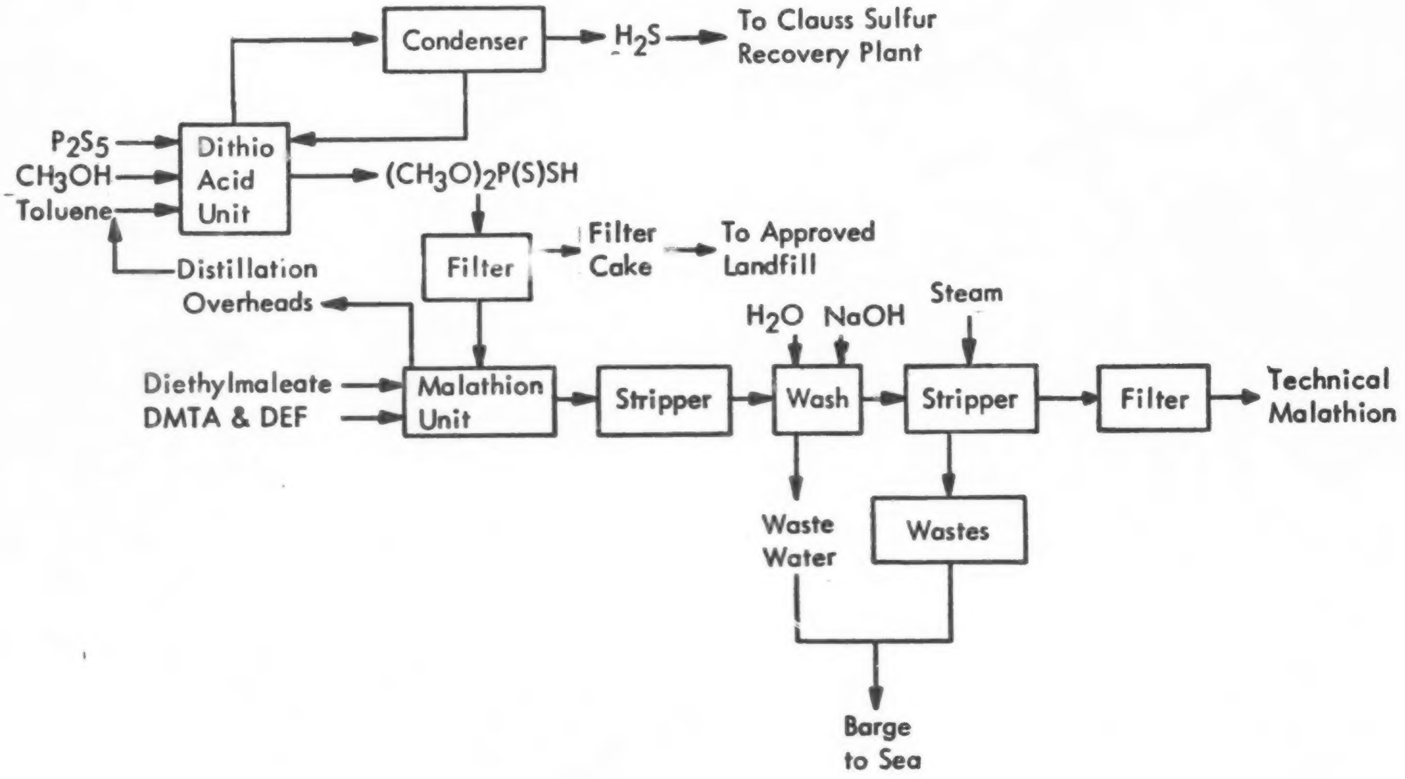

Condenser
H_2S
To Clauss Sulfur Recovery Plant
P_2S_5
CH_3OH
Toluene
Dithio Acid Unit
$(CH_3O)_2P(S)SH$
Filter
Filter Cake
To Approved Landfill
Distillation Overheads
Diethylmaleate
DMTA & DEF
Malathion Unit
Stripper
H_2O
NaOH
Wash
Steam
Stripper
Filter
Technical Malathion
Waste Water
Wastes
Barge to Sea

Figure 19 - Production and Waste Schematic for Malathion1/

is cleaned only once or twice a year and waste is also barged to sea. The only solid wastes are filter wastes. These are decontaminated with NaOH and buried with lye in a landfill. Dust in the formulation area is collected in a baghouse and recycled. The company tries to use the same containers (rail cars, trucks, etc.) over each time.

A batch process is used by American Cyanamid in their manufacture of malathion. Production is in equipment used only for malathion and other organophosphates. The raw materials for the process are received by truck and rail.

D. Formulation, Packaging, and Distribution

A variety of malathion formulations are available; a malathion ULV concentrate (9.8 lb/gal.), malathion 1000E emulsifiable (8.34 lb/gal.), malathion 500 (4.18 lb/gal.), malathion 57% and 95% (5 lb/gal. and 9.7 lb/gal., respectively). Less important products are pressurized formulations, malathion 400 TF Special (4.58 lb/gal.-thermal fogging insecticide, and 50% and 25% water dispersable powders. Most formulations are packaged in lined drums and shipped by rail and truck.

E. Use Patterns

General : Malathion was the first organic phosphate insecticide of low mammalian toxicity. It has been in large scale commercial use in the U.S. and in other countries for more than 20 years. Malathion controls a wide variety of economically and hygienically important insect pests that affect man, animals, plants and stored products. It is one of the least toxic synthetic insecticides, rated only "slightly toxic" to most nontarget species, except fishes. Malathion can readily be formulated with common solvents or mixed with other pesticides. It is rapidly degraded after application, and relatively inexpensive. These favorable properties make malathion useful for a great variety of insect control purposes in crop and livestock protection, public health, in and around homes, gardens, commercial premises, and in quarantine programs involving treatment of large areas, including populated areas.

Agricultural and home and garden uses of malathion each accounted for about one-third of the estimated U.S. consumption in 1972, the balance consisting of industrial, commercial and governmental uses.

Action : Broad-spectrum insecticide; contact and stomach poison; inhibits cholinesterase, stimulates the nervous system.

Target Crops : Forage crops and rangeland; fruit and vegetable crops; cotton; ornamentals; many other corps; forest and shade trees; mosquito control; control of insects affecting man, animals and stored products.

Target Pests : Grasshoppers, aphids, thrips, scales, army worms, plant bugs, mites, mosquitoes, flies, animal ectoparasites, and many other insects. Resistance is a problem in some areas, especially with aphids, mites, houseflies and mosquitoes.

Application : Foliar spray applications by ground or air equipment. Use of the undiluted ULV concentrate is a very efficient application technique, especially for large acreages. Commercial premises, homes, stored products and other non-crop targets are most often treated by spray equipment.

Rates of Application : 0.5-1.25 lb AI/acre for most uses on crops and rangelands, up to 4 lb AI/acre for some uses on row crops.
0.5-0.75 lb AI/100 gal. on fruit crops, up to 1.25 lb AI/100 gal. for some uses.
4.0-6.0% dusts or 0.6-1.25% AI sprays on animals.

Frequency : 1 to 8-10 applications per season or per year.

Time of Application : On crops, throughout the growing season. Other uses, throughout the year as required.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
24	0.2	8	16.2

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Sub-Totals	Home and Garden[a]	Totals
NE	0.2	0.3	0.1	1.1		
SE	1.5	0.8	1.2	3.5		
NC	1.0	1.2	0.3	2.5		
SC	0.6	0.8	0.4	1.8		
NW	0.7	0.2	0.1	1.0		
SW	1.0	0.2	0.1	1.3		
Totals	5.0	4.0	2.2	11.2	5.0	16.2

---

a/ Geographic distribution not known.

A materials flow diagram for malathion is shown in Figure 20.

F. Alternatives

Chemicals : A number of other organic phosphate and carbamate insecticides, including some of moderate or low mammalian toxicity (diazinon, fenthion, chlorpyrifos, carbaryl, propoxur, and others) are available for control of many of the insects against which malathion is used. None of these other insecticides offer the same combination of properties as malathion, i.e., broad insecticidal spectrum, low acute and chronic toxicity to mammals, low toxicity to most nontarget species, lack of persistence, suitability for ULV (ultra-low volume) application, and low cost.

Nonchemical : Biological control agents and integrated pest management programs are being developed for some of the crops on which malathion is used, especially cotton, fruit and vegetable crops. Malathion is employed in some of these, for instance, for control of diapausing boll weevils in integrated cotton pest management. For many other insects controlled by malathion, such as grasshoppers, animal ectoparasites, fruitflies, mosquitoes and other insects of public health importance, there are no effective nonchemical control methods available.

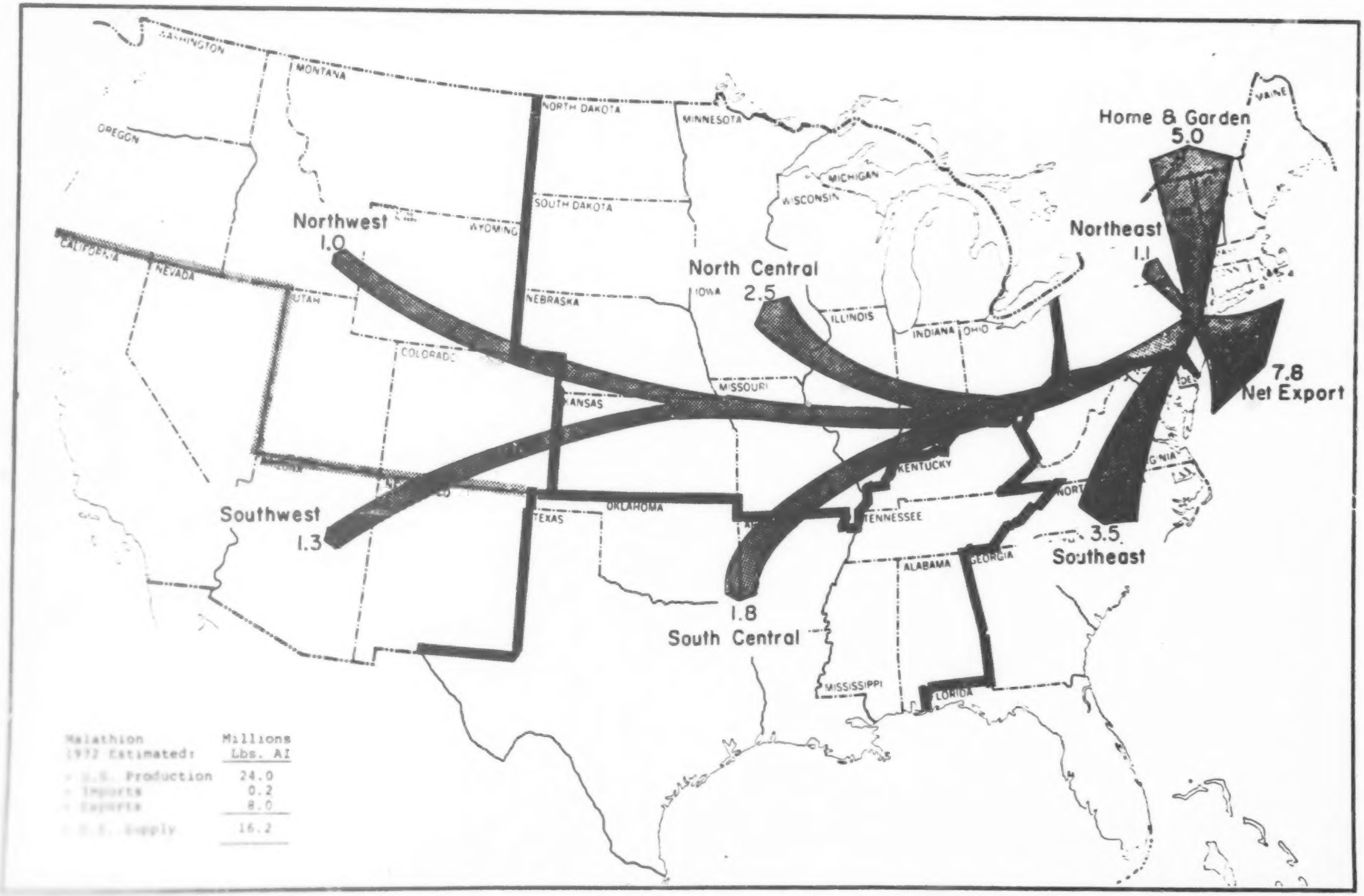

Home & Garden
5.0
Northeast
1.1
7.8
Net Export
3.5
Southeast
North Central
2.5
South Central
1.8
Northwest
1.0
Southwest
1.3
WASHINGTON
OREGON
CALIFORNIA
NEVADA
MONTANA
UTAH
WYOMING
COLORADO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
MAINE
Malathion
1972 Estimated:
Millions
Lbs. AI
+ U.S. Production 24.0
+ Imports 0.2
- Exports 8.0
= U.S. Supply 16.2

Figure 20 - Materials Flow Diagram for Malathion

G. Environmental Impact Potential

Mammalian Toxicity : Malathion is slightly toxic to laboratory mammals in acute toxicity tests via the oral and dermal routes. In acute inhalation toxicity tests, a lethal concentration was not achieved. Malathion is not irritating to eyes, nose or throat. It may be slightly irritating to the skin in sensitive persons. No cumulative toxic effects have been reported. Malathion formulations require the signal word "Caution" on the label. In chronic toxicity tests, the no-effect level in the diet of rats was 100 ppm. Tolerances for malathion residues have been established for a large number of crops and commodities, ranging from 1 to 135 ppm, 8 ppm on most crops.

In laboratory studies it was found that the toxicity of malathion to experimental animals is markedly increased if it is applied in conjunction with certain other organic phosphate chemicals that inhibit enzyme systems that detoxify malathion in vivo. This type of potentiation between certain organic phosphate insecticides has been investigated extensively in numerous laboratory studies. Tolerances for malathion and other cholinesterase inhibiting pesticides have been established with due consideration to their potentiating effects, if any. To date, there are no reports of adverse effects on human health from this phenomenon.

Nontarget Organisms : Malathion is highly toxic to fishes; moderately toxic to lower aquatic organisms, birds, and to soil insects; relatively nontoxic to wild mammals and soil organisms other than insects. In actual field experience, fish kills from the use of malathion have been reported only in a few instances, involving small fish in shallow waters that were directly treated. In several area-wide control projects in which thousands or even millions of acres were treated with malathion (for control of Mediterranean fruitfly, forest and rangeland insects, and cereal leaf beetles), there were no confirmed reports of adverse effects on fish, wild mammals or birds.

Malathion does not build-up in food chains. It is highly toxic to honeybees and to beneficial insects (predators and parasites) on direct contact, but plant residues dissipate rapidly after application.

Environment : Insecticidally effective malathion residues persist for 1 to 3 days on most treated crops, for 2 to 4 weeks on protected indoor surfaces, and for 3 to 12 months in stored products. Soil residues are not persistent and break down in less than 2 weeks.

Volatilization of malathion residues is possible, but does not appear to be a major mode of dissipation. Leaching from the soil is possible, based on laboratory studies and the product's physical and chemical properties. It is not likely to occur to a significant extent under field conditions because malathion is not recommended for applications into the soil, and because it is degraded rapidly in soil. For the same reasons, malathion is not likely to migrate appreciably from target areas by way of surface run-off in water or on solids. It is readily degradable by microbial action, sunlight and chemical hydrolysis. Metabolism and degradation of malathion proceed through several different chemical pathways, all of which yield innocuous end products. One metabolite, malaoxon, is considerably more toxic than the parent compound, but it is transitory and is quickly further metabolized and inactivated.

Evaluation : No hazards to human health are known to be associated with the use of malathion as an insecticide in accordance with label directions. There are no indications of hazards to terrestrial or aquatic ecosystems outside of target areas and their vicinities from the use of malathion. Malathion is one of the most benign pesticides available today.

CASE STUDY NO. 8. METHYL PARATHION

A. Product Description

Chemical Name: 0,0-Dimethyl 0-p-nitrophenyl phosphorothioate

Trade Names: Dalf, Folidol M, Metron, Nitrox 80, Partron M, Tekwaisa

Pesticide Class: Broad-spectrum nonsystemic insecticide; organophosphate

Properties: Low melting solid (m.p. 36.5°C), low solubility in water; very toxic; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Monsanto Company	Anniston, Alabama	50 million lb	28 million lb
Stauffer Chemical Company	Mount Pleasant, Tennessee	30 million lb	16 million lb
Kerr-McGee Chemical Corporation[b]	Hamilton, Mississippi	9 million lb	6 million lb
	Los Angeles, California	3 million lb	0.5 million lb
Velsicol Chemical Corporation[c]	Bayport, Texas	10 million lb	0.5 million lb

---

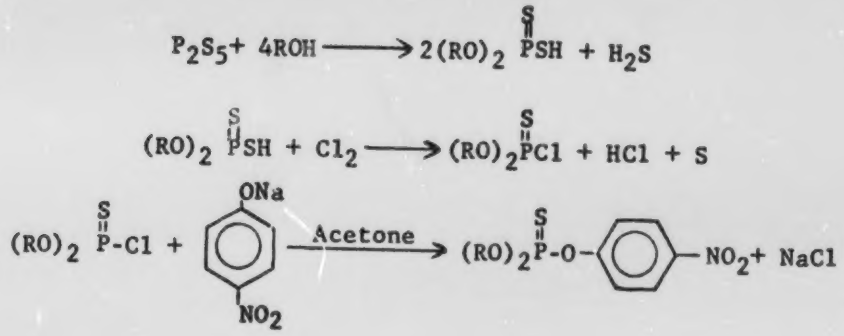
[a] Plant capacities are usually for methyl plus ethyl parathion.

[b] Kerr-McGee increased the capacity of its Hamilton plant to 14.5 million lb/year in 1973 and planned a further increase to 17 million lb/year in late 1974. Production of both methyl and ethyl parathion at the Los Angeles plant was terminated at the end of 1972.

[c] Velsicol has reportedly converted its methyl parathion facilities to another organophosphate since 1972.

C. Production Methods and Waste Control Technology

Information on Monsanto's production methods and waste control technology for methyl parathion have been reported.[1] The reaction chemistry is:



$$P_2S_5 + 4ROH \longrightarrow 2(RO)_2\overset{S}{\overset{\|}{P}}SH + H_2S$$

$$(RO)_2\overset{S}{\overset{\|}{P}}SH + Cl_2 \longrightarrow (RO)_2\overset{S}{\overset{\|}{P}}Cl + HCl + S$$

Monsanto produces methyl parathion by a batch process in equipment dedicated to methyl and ethyl parathion production. Two of the raw materials are produced on site and the rest are received by rail.[1/] A production and waste schematic is shown in Figure 21.

Liquid wastes from Monsanto's production, including by-product HCl-NaCl, go to biological treatment facilities and then into the Anniston sewer system. By-product H_2S is flared, sulfur and waste solvent are burned. The only solid waste is sludge from the biological oxidation system which is recycled and discharged at a slow rate into the sewer. Spills are washed into the waste treatment system. Outside spills are handled by Monsanto personnel and soda ash is used for decontamination. Equipment is cleaned 1 to 2 times per year.[1/]

Stauffer's method of producing methyl parathion is believed to be similar to Monsanto's, although an interview visit could not be arranged.

Kerr-McGee declined to discuss their methyl parathion plant. The Kerr-McGee plant at Hamilton does not produce either P_2S_5 or the nitrophenol; they apparently purchase P_2S_5 or possibly $(CH_3O)_2P(S)Cl$

D. Formulation, Packaging, and Distribution

Methyl parathion is sold as the technical product and as several formulations. Emulsifiable concentrates are by far the most important product; wettable powders and dust are very minor. Methyl parathion is often formulated as a combination with other insecticides, especially toxaphene.

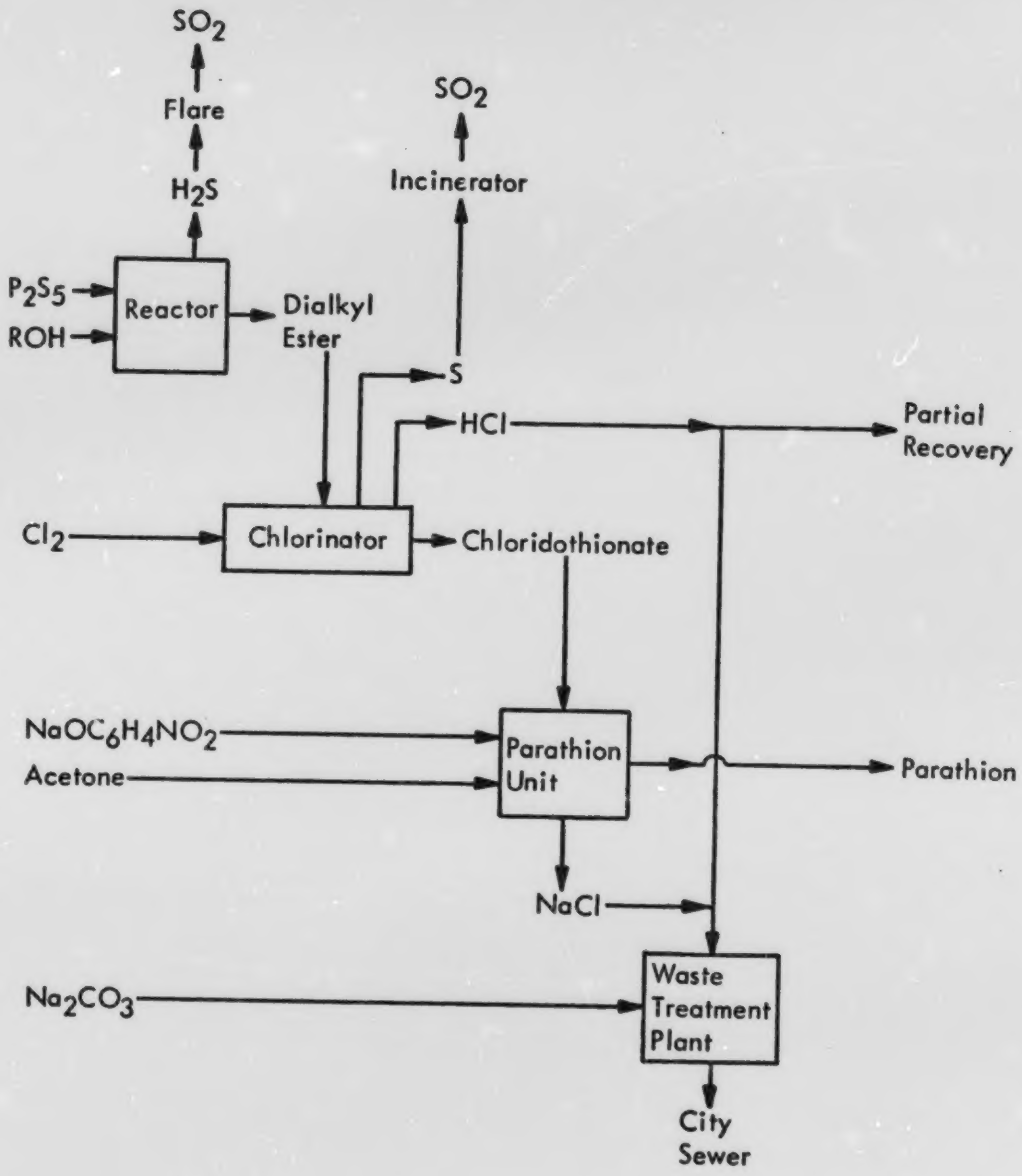

SO_2
Flare
H_2S
SO_2
Incinerator
P_2S_5
ROH
Reactor
Dialkyl Ester
S
HCl
Partial Recovery
Cl_2
Chlorinator
Chloridothionate
$NaOC_6H_4NO_2$
Acetone
Parathion Unit
Parathion
NaCl
Na_2CO_3
Waste Treatment Plant
City Sewer

Figure 21 - Production and Waste Schematic for Methyl Parathion (Monsanto)1/

Monsanto has the following methyl parathion formulations: 2 lb/gal., 4 lb/gal., 5 lb/gal., 7 lb/gal., and an 80% AI-10% xylene solution (7.5 lb/gal.). Stauffer also produces a technical methyl parathion of 80% AI. Monsanto markets the technical product in 55-gal. lined drums that are shipped mostly by truck (~ 10% of production is shipped by rail). Monsanto formulations are packaged in 5- and 55-gal. drums.

E. Use Patterns

General : Worldwide as well as in the U.S., methyl parathion is one of the most widely used cotton insecticides. It has been commercially available for about 25 years. Its volume of use began to level off some years ago, but started on a renewed upward trend recently as a result of the cancellation of the DDT registrations, and because of increasing use on soybeans. Methyl parathion is highly toxic to humans and to most other nontarget organisms. It is less stable and less toxic via the dermal route than its diethyl homolog, parathion.

There were no significant nonagricultural uses of methyl parathion in the U.S. in 1972.

Action : Broad-spectrum insecticide; contact, stomach and inhalation poison. Strong cholinesterase inhibitor. Stimulates the nervous system.

Target Crops : Cotton; soybeans; alfalfa; some other field and forage crops; some vegetable crops.

Target Pests : Cotton boll weevil, bollworm complex, alfalfa weevil; aphids, mites, leafhoppers, fleahoppers, plant bugs, beetles, and some other insects on crops; mosquito larvae. Resistance of the bollworm complex, loopers, mites and mosquitoes is a problem in some areas.

Application : Foliar application by ground or air equipment, often in combination with toxaphene or other insecticides.

Rates of Application : 0.25-1.0 lb AI/acre.

Frequency : Cotton, 3-10 or more applications per season. Other crops, 1-4 applications per season.

Time of Application : Late spring to the end of the growing season.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
51.1	1.1	12.5	39.7

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

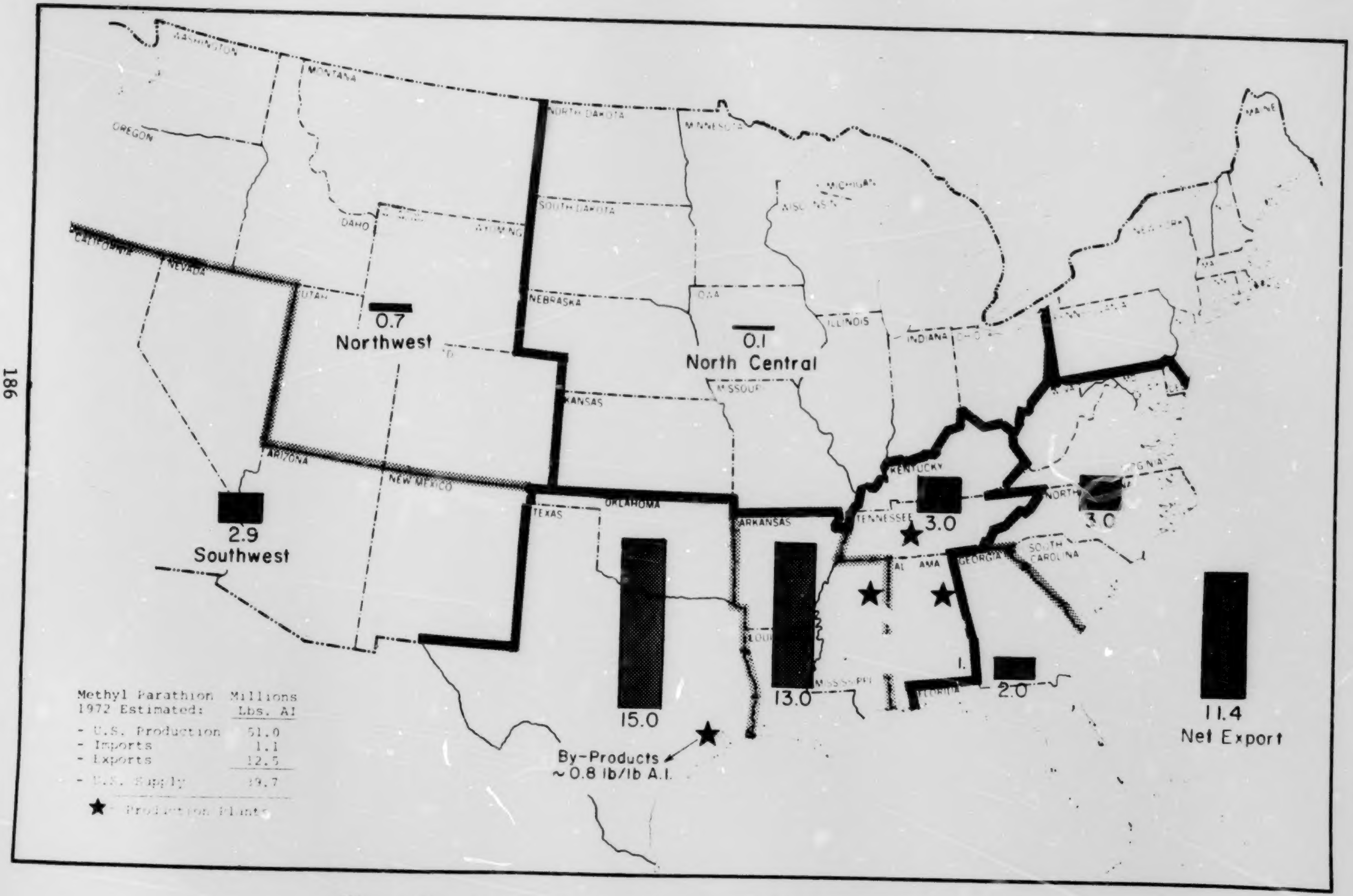
Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	Negligible				--
SE	5.0				5.0
NC	0.1				0.1
SC	31.0				31.0
NW	0.7				0.7
SW	2.9				2.9
Totals	39.7	Negligible	Negligible	Negligible	39.7

A materials flow diagram for methyl parathion is shown in Figure 22.

F. Alternatives

Chemicals : A number of other insecticides, including azinphos-methyl, malathion, carbaryl, and others are effective against the cotton, alfalfa, soybean and other field, forage and vegetable insects controlled by methyl parathion, but most of these are more expensive per unit of insect control.

Nonchemical : Several nonchemical methods for control of cotton, alfalfa, and soybean insects are currently under development. Integrated insect management programs in which these methods are combined with selective use of chemical insecticides have been developed to the point where they are practiced commercially on an increasing acreage.


WASHINGTON
OREGON
CALIFORNIA
NEVADA
MONTANA
IDAHO
WYOMING
UTAH
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH
VIRGINIA
NEW YORK
MAINE
0.7
Northwest
0.1
North Central
2.9
Southwest
15.0
13.0
3.0
3.0
2.0
1.
11.4
Net Export
By-Products
~0.8 lb/lb A.I.

Methyl Parathion 1972 Estimated:	Millions Lbs. AI
- U.S. Production	51.0
- Imports	1.1
- Exports	12.5
- U.S. Supply	39.7

★ - Production Plants

Figure 22 - Materials Flow Diagram for Methyl Parathion

G. Environmental Impact Potential

Mammalian Toxicity : Methyl parathion is highly toxic to laboratory animals by oral and dermal routes. Since it has a very low vapor pressure at ambient temperatures, vapor inhalation does not present a significant hazard. This statement does not apply to airborne particulates, such as dust or spray particles. In agricultural operations, methyl parathion is commonly applied by spray equipment as a liquid. Therefore, precautions should be observed to avoid the inhalation of spray mist. Methyl parathion is not irritating to eyes or skin. It may be irritating to the respiratory tract. There are no reports of skin sensitization. Methyl parathion is rapidly absorbed through the intact mammalian skin. However, it is somewhat less toxic via the dermal route than its diethyl homolog, parathion. Poisoning through skin exposure is a frequent cause of pesticide accidents in the U.S. Probably at least in part due to this difference in dermal toxicity, methyl parathion has not caused nearly as many accidents among pesticide workers and bystanders as parathion, even though it has been used in much larger quantities than parathion in recent years.

Methyl parathion formulations require labelling as highly toxic pesticides, including the signal words "Danger - Poison" and skull and crossbones.

Continued exposure to sublethal doses of methyl parathion could result in cumulative toxic effects through progressive inhibition of cholinesterase.

No chronic toxicity studies on laboratory animals have been conducted with methyl parathion. Its chronic toxicity is believed to be similar to that of parathion. In a 30-day test on human volunteers, daily doses of 7, 7.5, 8 and 9 mg did not depress cholinesterase by more than 20% of the pre-established control values. Tolerances for residues of methyl parathion have been established for a number of crops, ranging from 0.05 to 5.0 ppm, 1.0 ppm for most crops.

Methyl parathion residues on treated plants dissipate more rapidly than those of parathion. Treated fields should not be re-entered by field workers within less than 48 hr after application, depending upon the crop, rate of application, weather conditions, and other factors.

Nontarget Organisms : Methyl parathion is moderately toxic to fishes, highly toxic to lower aquatic organisms, birds, wild mammals and to soil fauna. It is much less toxic to other soil organisms. There are no data on its possible buildup in food chains, but this is not likely to occur because it is rapidly degraded in plants, animals, microorganisms and water. Methyl parathion is highly toxic to honeybees and to other beneficial insects by direct contact or by contact with residues on plant surfaces soon after application.

Environment : Methyl parathion is not persistent in the environment. Residual insecticidal effectiveness persists for only 1 to 2 days on treated plants. Methyl parathion is not recommended for any applications directly into the soil. It is rapidly degraded in soil. Some quantities of methyl parathion may dissipate from treated surfaces by volatilization. Migration from treated areas by leaching or surface run-off in water or on solids is possible based on laboratroy studies, but is not likely to be of importance in the field because methyl parathion degrades so rapidly. It is readily degradable by biological organisms as well as by nonbiological factors including sunlight. Several isomers and metabolites of methyl parathion are more toxic than the parent compound, but they are very transitory due to their instability. Degradation mechanisms include hydrolysis, oxidation, reduction, and dealkylation.

Evaluation : All methyl parathion formulations (except dry formulations of less than 2% AI content) are highly toxic and present serious hazards to operators and persons entering treated areas soon after application without adequate protection.

Methyl parathion has a moderately broad spectrum of biological effectiveness. It is not persistent in the environment. There are no reports of gross adverse effects on terrestrial and/or aquatic ecosystems away from target areas from the use of methyl parathion as an insecticide in accordance with label directions.

CASE STUDY NO. 9. PARATHION (ETHYL PARATHION)

A. Product Description

Chemical Name: O,O-Diethyl O-p-nitrophenyl phosphorothioate

Trade Names: Alkron, Alleron, Bladan, Corothion, E-605, Ethyl Parathion, Ethlon, Folidol E-605, Niron, Orthophos, Panthion, Paramar, Parathene, Parawet, Phoskil, Rhodiatox, Soprathion, Stathion, Thiophos

Pesticide Class: Broad-spectrum nonsystemic insecticide; organophosphate

Properties: Liquid of low volatility; insoluble in water; very toxic; nonpersistent.

B. Manufacturers

Name	Plant Location	Plant Capacity[a]	Estimated 1972 Production
Monsanto Company	Anniston, Alabama	50 million lb	10 million lb
Stauffer Chemical Company	Mt. Pleasant, Tennessee	30 million lb	3 million lb
Kerr-McGee Chemical Corporation	Los Angeles, California	3 million lb	1 million lb
	Hamilton, Mississippi	9 million lb	None

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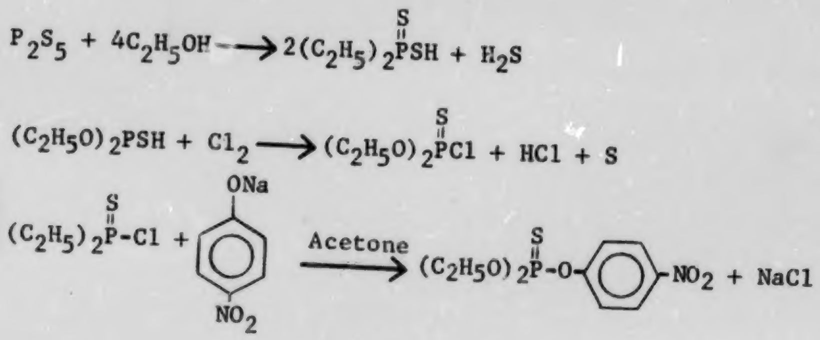
[a] Plant capacities are for methyl plus ethyl parathion. Stauffer discontinued parathion production in 1973.
Kerr-McGee discontinued parathion production at the Los Angeles location at the end of 1972 and has produced only methyl parathion at the Hamilton plant.

C. Production Methods and Waste Control Technology

Information on Monsanto's production method and waste control technology for parathion has been reported.[1]



$$P_2S_5 + 4C_2H_5OH \longrightarrow 2(C_2H_5)_2\overset{S}{\overset{\|}{P}}SH + H_2S$$

$$(C_2H_5O)_2PSH + Cl_2 \longrightarrow (C_2H_5O)_2\overset{S}{\overset{\|}{P}}Cl + HCl + S$$

Monsanto produces parathion as it does methyl parathion; batch process equipment dedicated to methyl parathion and parathion production, and some of the raw products shipped by rail. The production and waste schematic for methyl parathion, Figure 21, is applicable to parathion. The comments on Stauffer's and Kerr-McGee's methyl parathion were applicable to parathion, although neither of these companies are currently parathion producers.

D. Formulation, Packaging, and Distribution

Monsanto packages technical parathion in 55-gal., lined drums that are shipped mostly by truck. Parathion is formulated in 2-, 4-, 6-, and 8-lb/gal. emulsifiable concentrates packaged in < 5-, 5-, 15-, 30-, and 55-gal. drums. In addition, parathion is available in 1%, 2%, 20%, and 25% dusts, granules or wettable powders. The technical grade parathion manufactured by Stauffer Chemicals has 98.5% active ingredient.

E. Use Patterns

General : Parathion was the first commercially successful organic phosphate insecticide. It has been on the market for about 25 years. It has a very broad spectrum of effectiveness and is currently registered in the U.S. for a large number and variety of uses; the parathion section in the EPA Compendium of Registered Pesticides is one of the most voluminous of all and comprises 163 pages.

Parathion is one of the most toxic pesticides. Worldwide, its use and misuse have caused more human deaths and accidents than any other pesticide. Parathion is also highly toxic to fishes, birds, and other nontarget organisms. Some countries have banned its use. In the U.S., its volume of use has continued at a high level, recently showing a further upward trend. Parathion has no significant uses in areas other than agriculture.

Action : Insecticide, very broad spectrum; contact, stomach and inhalation poison. Strongly inhibits cholinesterase. Stimulates the nervous system.

Target Crops : Cotton, vegetable crops, fruit and nut crops, corn, tobacco; numerous other agricultural and horticultural crops.

Target Pests : Aphids, plant bugs, leafhoppers, scales, mites; many other foliar and soil insects. Resistance of aphids, mites and some other insects fairly widespread.

Application : Foliar applications by ground or air equipment (grain and forage crops often treated by air); soil application by ground equipment.

Rates of Application : 0.25 - 1.0 lb. AI/acre for foliar treatments; higher rates, up to 10 lbs. AI/acre, for soil applications and certain other uses.

Frequency : Field crops, 1 - 3 applications per season. Fruit and vegetable crops, tobacco, up to 8 applications per season.

Time of Application : Foliar applications throughout most of the growing season, soil applications at planting time.

Estimated Distribution : (All figures in millions of lbs. AI/year, 1972)

U. S. Production	Imports	Exports	Domestic Consumption
14	Negl.	4	10

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	0.4				0.4
SE	1.4				1.4
NC	1.8				1.8
SC	3.5				3.5
W	2.9				2.9
Totals	10.0	Negligible	Negligible	Negligible	10.0

A materials flow diagram for parathion is shown in Figure 23.

F. Alternatives

Chemicals : Many other chemical insecticides (organic phosphates, carbamates and chlorinated hydrocarbons) are available for control of the pests against which parathion is used. Most of these alternative insecticides are less toxic to humans and to other nontarget species, but few, if any of them can compete against parathion in regard to cost effectivenesss.

Nonchemical : Biological control agents and integrated pest management methods are being developed and employed against some of the insects controlled by parathion, especially cotton and fruit insects.

G. Environmental Impact Potential

Mammalian Toxicity : Parathion is extremely toxic to laboratory animals by the oral and dermal routes. No laboratory data are available on its acute inhalation toxicity, but all indications are that it is extremely toxic by this route also. Parathion is not irritating to the eyes, respiratory tract or the skin. Dermal toxicity studies indicate that about a teaspoon of parathion left on the skin of a human (or a single drop of parathion metabolite, paraoxon, in the eye of a rabbit) could be fatal. Parathion is rapidly absorbed through the intact mammalian skin. All parathion formulations above 2% AI require labeling as highly poisonous pesticides, including the signal words "Danger - Poison" and skull and crossbones.

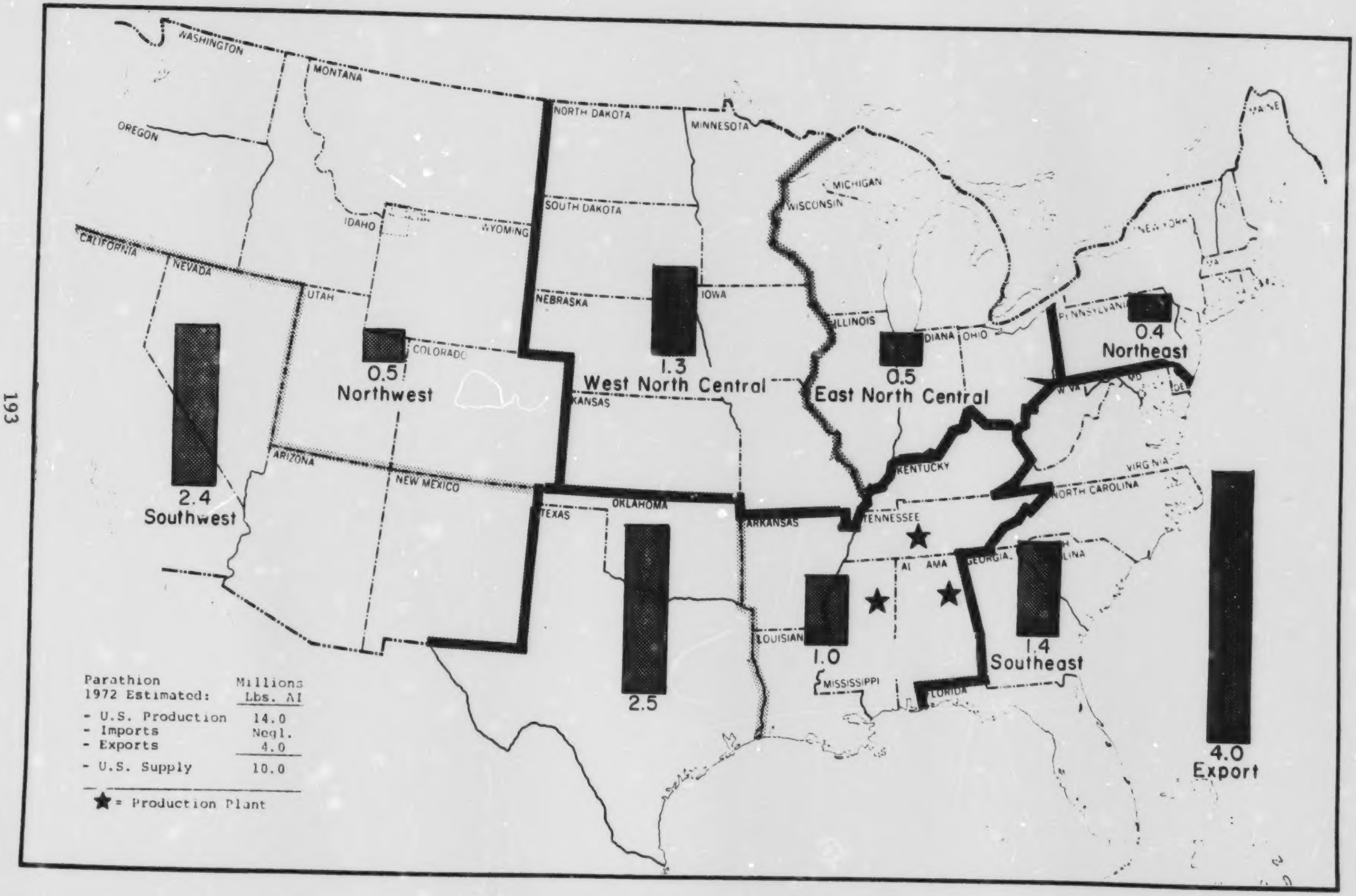

WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
ARKANSAS
LOUISIAN
MISSISSIPPI
WISCONSIN
MICHIGAN
ILLINOIS
DIANA
OHIO
KENTUCKY
TENNESSEE
AL AMA
GEORGIA
LORIDA
NORTH CAROLINA
LINA
VIRGINIA
W VA
PENNSYLVANI
NEW YORK
DE
MAINE
2.4
Southwest
0.5
Northwest
1.3
West North Central
2.5
0.5
East North Central
1.0
1.4
Southeast
0.4
Northeast
4.0
Export
Parathion
1972 Estimated:
Millions
Lbs. AI
- U.S. Production 14.0
- Imports Negl.
- Exports 4.0
- U.S. Supply 10.0
★ = Production Plant

Figure 23 - Materials Flow Diagram for Parathion, 1972

In chronic toxicity tests, the no-effect level (including observation of cholinesterase inhibition) in the diet was 1 ppm for rats and dogs, 50 ppm for mice. In a subacute study on man, 0.05 mg/kg of body weight per day (equivalent to 1 ppm in the diet) was the no-effect level. Continued exposure to sublethal dose levels of parathion will produce progressive inhibition of cholinesterase. Tolerances for parathion residues have been established for a large number of crops, ranging from 0.1 to 5.0 ppm, 0.7 ppm for most commodities.

Parathion residues on treated plants may be dangerous to field workers such as fruit pickers, insect scouts, flagmen directing aerial applications, and others. Treated orchards, field crops and other plantings should not be entered by unprotected persons within 48 hr after application, depending upon crops, application rates, weather conditions, and other factors.

Nontarget Organisms : Parathion is highly toxic to fishes, lower aquatic organisms, birds, wild mammals, and to soil fauna. It is moderately toxic to other soil organisms. Parathion is also highly toxic to honeybees and to other beneficial insects (predators and parasites) by direct contact, as well as through indirect contact with residues on plant surfaces.

A small amount of parathion accumulates in fish and mussels when they are exposed to continued low concentrations in water, but are eliminated when exposure ceases. There are no data on its buildup in food chains.

Environment : Parathion is moderately persistent in the environment. Residual insecticidal effectiveness persists for several days, sometimes longer, on exposed plant surfaces, for 1 month or more on protected surfaces such as bark. Parathion residues in the soil are moderately persistent. Soil degradation rates vary greatly, depending upon temperature, moisture, pH and other conditions. Generally, there is no carryover of residues to the next season.

Parathion may dissipate to some extent from treated areas by volatilization. It may also migrate by way of leaching or surface run-off in water or on solids. Parathion is degradable biologically and by nonbiological factors including sunlight. Its metabolism in vivo includes oxidation to paraoxon, a more toxic, but less stable, analog. Other degradation products formed by hydrolysis and dealkylation include phosphoric and phosphorothioic acids and nitrophenol, all less acutely toxic than the parent compound.

Evaluation : All parathion formulations (except granules of low AI content) are extremely dangerous poisons. Labels of parathion products set forth all warnings and precautionary measures necessary for the protection of operators. However, these measures are so severe that they are often disregarded, especially under hot and humid climatic conditions where physical labor in "waterproof pants, coat, hat, rubber boots or overshoes, safety goggles, mask or respirator, and heavy duty natural rubber gloves" (quoted from a product label) is uncomfortable or possibly stressful. Thus, parathion has caused many illnesses among operators, some of them fatal. In the United States, parathion has caused an even larger number of accidental poisonings and deaths among persons not directly involved in the pesticide application itself, especially young children. Such accidents have resulted from careless handling or storage of parathion products, application equipment or containers, and from exposure to spills. Children have become poisoned from playing with contaminated equipment, measuring cups, dirt, mudpies, etc., or heavily contaminated vegetation or bare ground. In other countries, spillage of liquid parathion on flour, stacks of clothing or other commodities, and other mishaps with the product have resulted in many deaths and illnesses.

Thus, parathion is a highly dangerous insecticide that has great potential for harm to nontarget species, including man.

CASE STUDY NO. 10. TOXAPHENE

A. Product Description

Chemical Name: Mixed Isomers of Chlorinated Camphene (67-69% chlorine)

Trade Names: Clor Chem T-590, Phenacide, Phenatox, Strobane-T, Toxakil

Pesticide Class: Broad spectrum insecticide; Chlorinated hydrocarbon

Properties: Waxy solid, insoluble in water; moderately toxic; low persistence compared to DDT

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Hercules, Inc.	Brunswick, Georgia	50-75 million lb	50-75 million lb
Tenneco Chemicals, Inc.	Fords, New Jersey	125 million lb	20 million lb

The production of toxaphene in 1972 is difficult to estimate. The Tariff Commission reports that production of the aldrin-toxaphene group has increased substantially since 1970 and was even higher in 1972 than it was in 1966, as shown in Table XXXI. Among the seven components of the group, productions of chlordane, dieldrin, endrin and heptachlor are believed to have been fairly constant since 1966, and the major changes have been in production of aidrin (which peaked in 1966), toxaphene and Strobane®. Individual estimates are:

Pesticide	Estimated Production (million lb) 1966	1970
Aldrin	19	9
Chlordane	20	20
Endrin	2	1
Dieldrin	1.5	0.6
Heptachlor	8	8
Strobane®	15	-
Toxaphene	65	50[a]
Tariff Commission Total	130.5	88.6

---

[a] Includes Strobane-T®

TABLE XXXI

PRODUCTION OF THE ALDRIN-TOXAPHENE GROUP, 1963-1972

Year	Production (MM lb)[a]	Reported Toxaphene Producers
1963	106.0[b]	Hercules
1964	105.3	Hercules
1965	118.8[c]	Hercules
1966	130.5[c]	Hercules
1967	120.2[c]	Hercules, Sonford
1968	116.0[c]	Hercules
1969[d]	123.1[c]	Hercules
1970	88.6	Hercules, Sonford, Tenneco
1971	116.3	Hercules, Sonford, Tenneco
1972	141.9	Hercules, Tenneco[e]

---

[a] Source: U.S. Tariff Commission.

[b] The aldrin-toxaphene group contains aldrin, chlordane, dieldrin, endrin, heptachlor, and toxaphene. Before 1963, production data for these products were included in the broad "chlorinated hydrocarbon insecticide" category (along with DDT).

[c] Production data for Tenneco's polychlorinated terpene product, Strobane® (a toxaphene-like insecticide first produced in 1964) is included from 1965 through 1969.

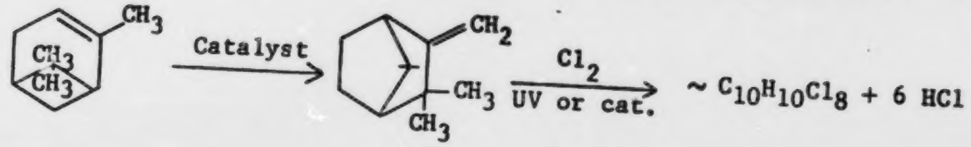
[d] Production data for 1969 were from the preliminary reports; only the sales figures of 110.4 was given in the final report.

[e] Sonford's facilities at Port Neches, Texas, which had a small toxaphene capacity, are now operated by Bison Chemical Company, but are not believed to be producing toxaphene. Helena Chemical Company may produce toxaphene at Vicksburg, Mississippi in 1974.

But if aldrin production was 11-13 million pounds in 1972, and that of the other components totaled about 32 million pounds, then toxaphene production must have reached the unprecedented total of about 95 million pounds. While one industry source has indicated that this estimate is reasonable, another has stated that it is implausibly high, and that 75 million pounds would be a maximum. If the higher figure is accurate, the 75 million pounds figure represents a good 5-year average.

C. Production Methods and Waste Control Technology

Information on production methods and waste control technology for toxaphene have been reported.[1/] The reaction chemistry is:



α-Pinene

Camphene

Toxaphene (mixed isomers and related compounds 67-69% Cl)

A production and waste schematic for Hercules' process is shown in Figure 24.

Hercules receives the raw products for its toxaphene production by tank cars, truck, and rail.

The effluent from the camphene production step goes to the main plant waste stream which is discharged into a tidal creek. Toxaphene production area is diked. The liquid waters go to large holding pond and waste treatment system. Process vents are water, caustic, or lye-scrubbed before venting with scrubber water going to the holding pond. Effluent from treatment plant goes to a creek, then to the ocean. Baghouses are used in the dust concentrate unit and the dust is recycled. Tank cars, whether company owned or rented, are dedicated. They are cleaned yearly with washings going to the toxaphene recycle sytem and aqueous wastes through the waste treatment system.

D. Formulation, Packaging, and Distribution

Most toxaphene is shipped in 90% toxaphene concentrate-10% xylene form in tanks (by rail and truck), in 55 gal. drums, and in 50 lb bags (palletized). A small amount of the technical product is packaged in 250 gal. galvanized drums and exported via the East Coast. The toxaphene is formulated as follows: 10% and 15% granular, 20% dust, and 6 lb/gal. and 8 lb/gal. emulsifiable concentrates. Other formulations are low-volume concentrates, wettable powders, solutions, combination formulations with other insecticides. These formulations are available under different brand names, and in varying concentrations of AI.

E. Use Patterns

General : Toxaphene is a heavily chlorinated camphene. Its exact chemical structure is not known. It has been in commercial use for about 25 years. At least during the last 10 years, it has been used in larger quantities in the U.S. than any other insecticide. Its most important use is in the control of cotton insects, usually in combination with DDT (up to 1973), methyl parathion, or other insecticides. Toxaphene can easily be formulated or mixed with other insecticides. It appears to act as a solubilizer for insecticides that have low solubility by themselves. Some combinations of toxaphene with other insecticides are reported to have synergistic properties.

Toxaphene is moderately toxic to mammals, not as persistent as most other chlorinated hydrocarbon insecticides, and quite inexpensive. Its level of use is still on the rise, due at least in part to the phasing out of DDT and increased toxaphene uses on cotton, soybeans, and other field crops. Nonfarm uses of toxaphene are very small.

Action : Broad-spectrum insecticide; contact and stomach poison. Stimulates the central nervous system.

Target Crops : Cotton; livestock; small grains; soybeans; corn; many other field, vegetable, fruit and nut crops, ornamentals.

Target Pests : Cotton insects, numerous other chewing, sucking and biting insects affecting above target crops or livestock. Resistance of some target pests is a problem in some areas; combinations with other insecticides widely used to overcome it. Some nontarget species (fish) in areas of heavy use of toxaphene have also developed resistance.

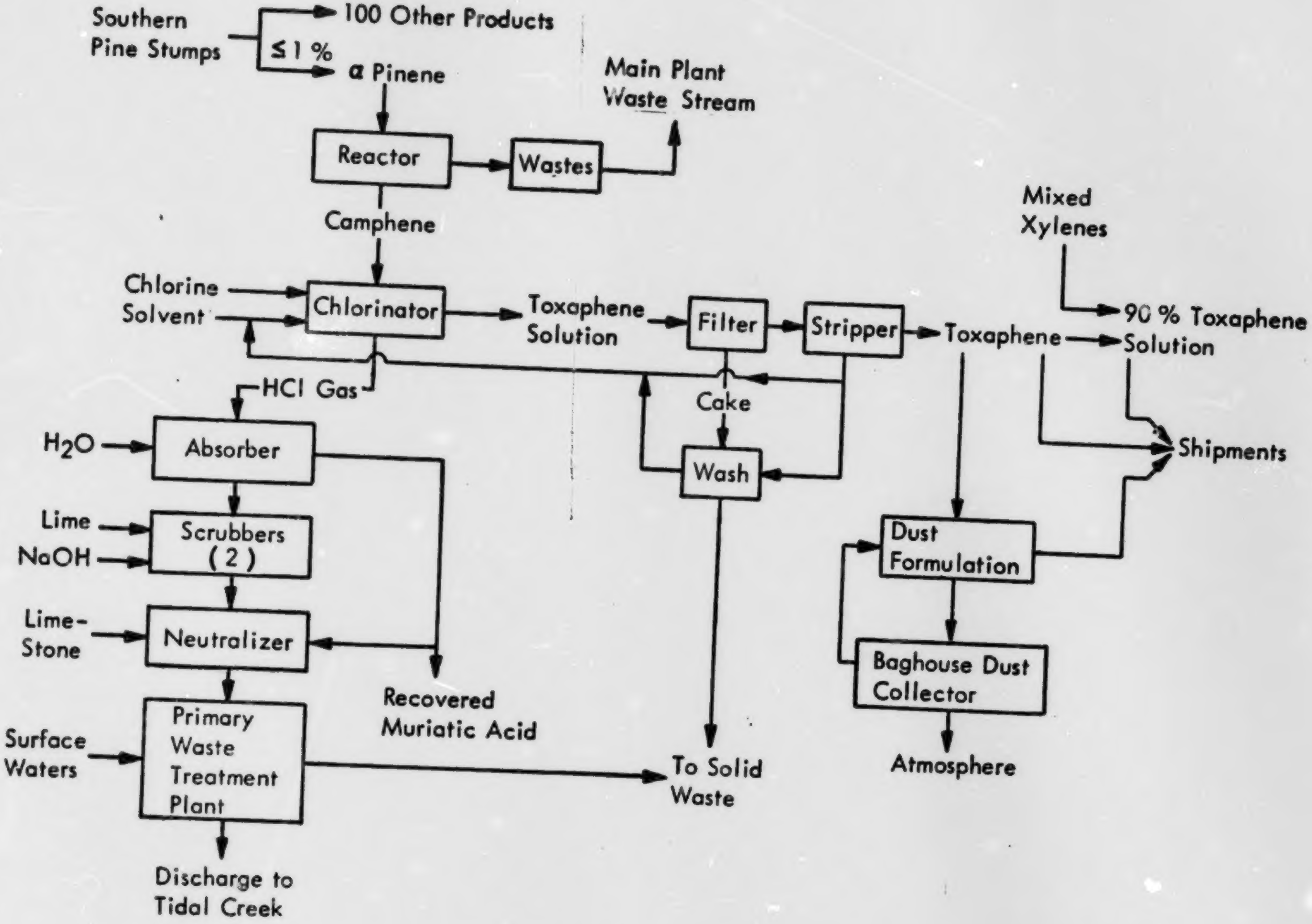

Southern Pine Stumps
100 Other Products
≤1 %
α Pinene
Reactor
Wastes
Main Plant Waste Stream
Camphene
Chlorine
Solvent
Chlorinator
Toxaphene Solution
Filter
Stripper
Toxaphene
Mixed Xylenes
90 % Toxaphene Solution
HCl Gas
Cake
Wash
Shipments
H2O
Absorber
Lime
NaOH
Scrubbers (2)
Lime-Stone
Neutralizer
Recovered Muriatic Acid
Dust Formulation
Baghouse Dust Collector
Atmosphere
Surface Waters
Primary Waste Treatment Plant
To Solid Waste
Discharge to Tidal Creek

Figure 24 - Production and Waste Schematic for Toxaphene (Hercules)1/

Application : Most important use is foliar application to crops by air or ground equipment, often in combination with other insecticides, especially DDT (up to 1973) and/or methyl parathion. Livestock treated in dip vats or by sprays ; some use of oil solutions in backrubbers and other self-application devices.

Rates of Application : 1.0-3.0 lb AI/acre on most crops; 1.0-1.25 lb AI/100 gal. of spray; 0.25-0.6% AI in livestock dips or sprays; 5.0-8.0% AI in livestock backrubbers; 5.0% dusts for use on livestock.

Frequency : On crops, 1-12 applications per season. On livestock, 1-4 applications per year.

Time of Application : On crops, throughout the vegetation season. On livestock, year around depending on pest problem.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972):

U.S. Production	Imports	Exports	Domestic Consumption
76[a]	None	18	58

---

[a] See pp. 196-198.

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	Negl.	0.2			0.2
SE	20.0	0.2			20.2
NC	1.0	0.2			1.2
SC	31.5	0.2			31.7
W	4.5	0.2			4.7
Totals	57.0	1.0	Small[a]	Small[a]	58.0

---

[a] Too small to break out, included in totals.

A materials flow diagram based on these estimates for toxaphene is shown in Figure 25.

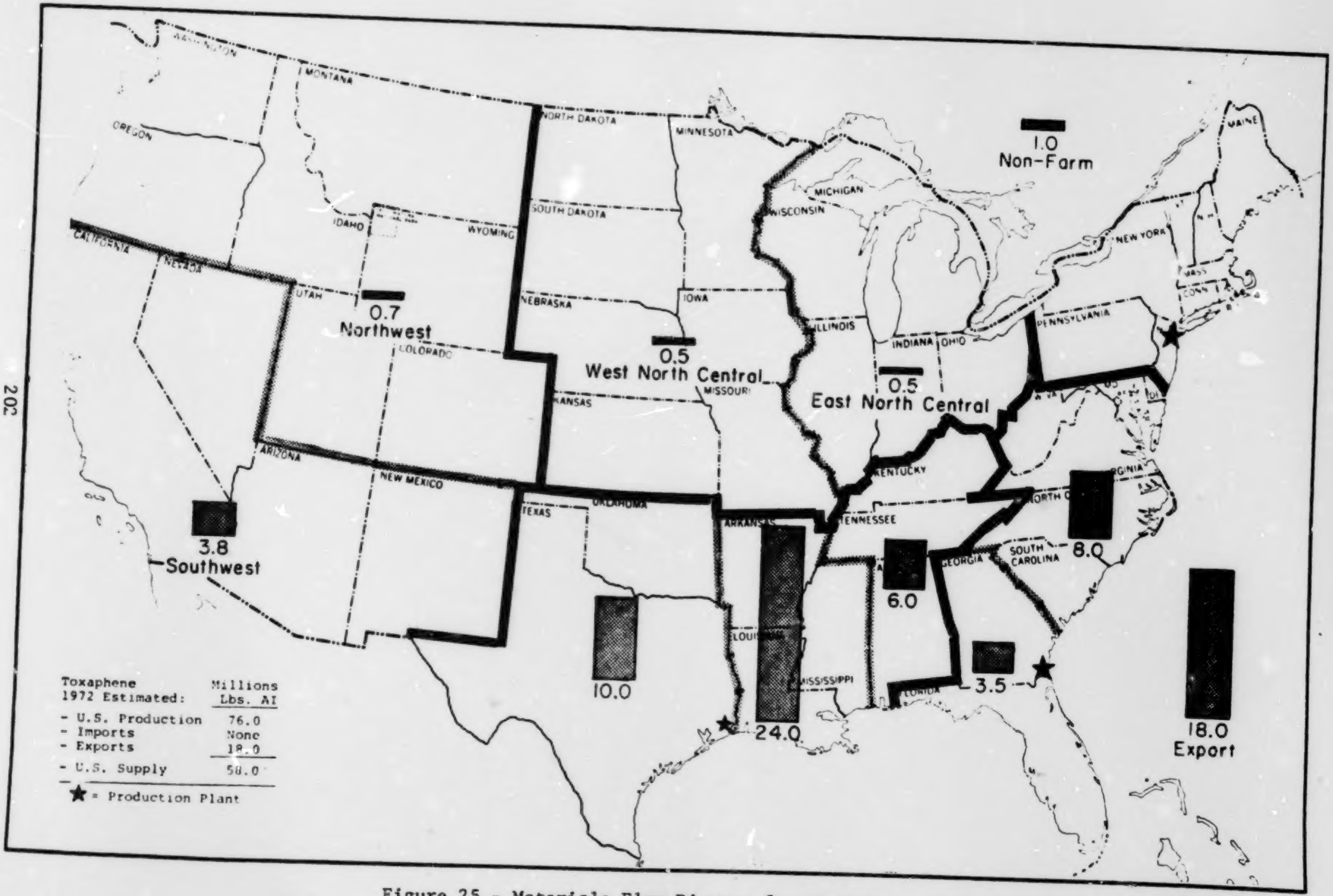

1.0
Non-Farm
0.7
Northwest
0.5
West North Central
0.5
East North Central
3.8
Southwest
10.0
24.0
6.0
3.5
8.0
18.0
Export
Toxaphene
1972 Estimated:
Millions
Lbs. AI
- U.S. Production 76.0
- Imports None
- Exports 18.0
- U.S. Supply 58.0
★ = Production Plant
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
NEW YORK
MASS
CONN
MAINE

Figure 25 - Materials Flow Diagram for Toxaphene, 1972

F. Alternatives

Chemicals : Against insects on farm crops: There are many other chemical insecticides that control some or most of the insects controlled by toxaphene. However, no other insecticide offers the same combination of broad insecticidal effectiveness, moderate mammalian toxicity and environmental persistence, ease of formulation and mixing, and low cost.

Against livestock insects, a number of other chemical insecticides are available.

Nonchemical : Several nonchemical methods for control of cotton and other insects are currently under development, including the use of bacterial and viral agents, and of insect attractants. Combination of these methods with the use of chemical insecticides only as needed in integrated pest management programs will reduce the quantities of toxaphene and/or other insecticides required for prevention of yield loss.

No specific, effective nonchemical methods are available for control of the livestock pests controlled by insecticides, such as lice, ticks, scabies, and mange. Good sanitation and husbandry practices help, but are often not sufficient by themselves.

G. Environmental Impact Potential

Mammalian Toxicity : In acute toxicity tests, toxaphene is moderately toxic to laboratory animals by the oral, dermal and inhalation routes. Toxaphene active ingredient by itself is not irritating to eyes, skin or the respiratory tract, but formulation ingredients may be irritating. Toxaphene formulations carry the signal word "Warning" on the label.

In chronic toxicity tests, the following no-effect levels were found: 25 ppm for the rat; 20 ppm for the dog; 0.7 mg/kg of body weight per day for the monkey. Tolerances for residues of toxaphene have been established for a large number of crops, ranging from 2 to 7 ppm, 7 ppm on most commodities.

Nontarget Organisms : Toxaphene is extremely toxic to fishes, and toxic to lower aquatic organisms, birds, and wild mammals. Its toxicity to soil organisms is not known. Toxaphene bioaccumulates and builds up in food chains, but not nearly to the same extent as the highly persistent chlorinated hydrocarbon insecticides.

Toxaphene is moderately toxic to honeybees and to beneficial insects (predators and parasites).

Environment : Toxaphene is not recommended for application directly into the soil. On treated plants, its residual insecticidal effectiveness persists for about 5 to 14 days. Its rate of volatilization from the surface of plants or soil is substantial; volatilization is believed to be the major mechanism of dissipation of toxaphene. If toxaphene penetrates into soil profiles, it becomes tightly bound to soil particles highly resistant to leaching. Run-off from treated plants or from the soil surface may be substantial. Toxaphene residues that have become adsorbed on soil particles may be transported by way of soil erosion and sediment transport.

Toxaphene is believed to be degradable by biological organisms as well as by nonbiological factors, but the rates and pathways are not known in detail. In the soil, toxaphene is very persistent, but it does not become incorporated into the soil in its normal use. Monitoring studies do not indicate any build-up of toxaphene in the environment, even though the product has been used in very large volumes in the United States for many years. In the National Soils Monitoring Program, toxaphene residues were found at only 4.2% of 1729 sites sampled. The range of toxaphene residues detected was 0.1 to 11.72 ppm, the mean level 0.07 ppm.

Evaluation : There is no evidence that serious hazards to human health are associated with the use of toxaphene as an insecticide in accordance with label directions. Toxaphene is severely toxic to aquatic ecosystems, especially to fishes. Toxaphene is also toxic to terrestrial ecosystems, but these effects are much less ubiquitous and widespread than those caused by the more persistent chlorinated hydrocarbon pesticides.

CASE STUDY NO. 11. ALACHLOR

A. Product Description

Chemical Name: 2-Chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide

Trade Names: Lasso, CP 50144, Lazo

Pesticide Class: Selective herbicide; Acetanilide

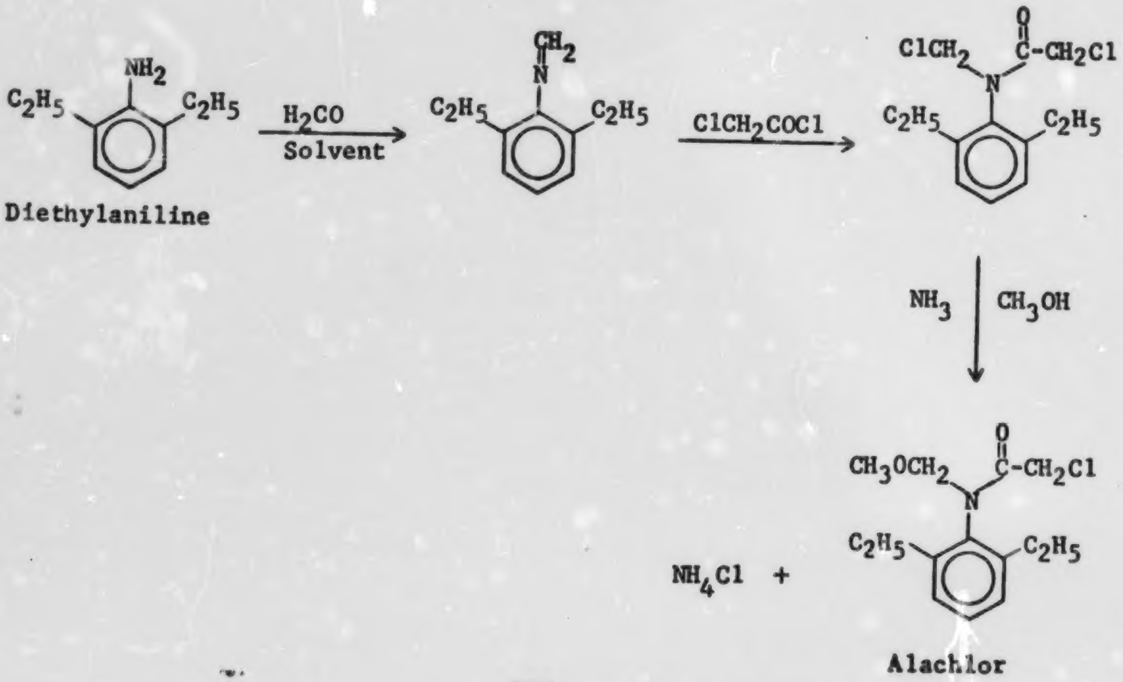
Properties: Low melting (40°C) solid; solubility in water, 140 ppm; moderately low toxicity; skin irritant; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Monsanto Company	Muscatine, Iowa	30 million lb	24 million lb

C. Production Methods and Waste Technology

Information on production and waste control technology for alachlor have been reported.[1] The reaction chemistry is:


NH$_2$
C$_2$H$_5$
C$_2$H$_5$
Diethylaniline
H$_2$CO
Solvent
CH$_2$
N
C$_2$H$_5$
C$_2$H$_5$
ClCH$_2$COCl
O
ClCH$_2$
C-CH$_2$Cl
N
C$_2$H$_5$
C$_2$H$_5$
NH$_3$
CH$_3$OH
O
CH$_3$OCH$_2$
C-CH$_2$Cl
N
C$_2$H$_5$
C$_2$H$_5$
NH$_4$Cl +
Alachlor

A production and waste schematic is shown in Figure 26.

The formulation equipment is not dedicated. The packaging area has automatic bagging and filling equipment. The production and warehouse areas are not diked. There is no problem with leakage. The used drums go to a landfill on site and wipe cloths are probably burned.

Formulation of the technical product is on site.

Process water is discharged into the Mississippi River after mechanical treatment only. The production equipment requires clean-up only two to three times per year.

Monsanto uses a batch process in their production of alachlor. The raw materials are received by truck, tank cars, and rail.

D. Formulation, Packaging, and Distribution

About 50-60% of the production is formulated into a 43% (4 lb/gal.) emulsifiable concentrate (Lasso® EC) packaged in 5 gal. lined cans shipped primarily by truck. The remaining 35-45% of production goes to Lasso® log (10% alachlor granular) packaged in 5 lb bags, again shipped mostly by truck and to a lesser degree, by rail.

E. Use Patterns

General :	Alachlor has been on the market only since 1969, but its volume has increased very rapidly due to its remarkable spectrum of selectivity that permits its use on three of the most important U.S. field crops, i.e., corn, soybeans and peanuts. Nonagricultural uses are negligible or nil. Further increase in volume of use is anticipated.
Action :	Selective, soil-applied, preplant or pre-emergence herbicide for control of annual grass weeds and some broadleaf weeds. Absorbed by germinating plant shoots. Mode of action not known.
Target Crops :	Corn, soybeans, peanuts.
Target Weeds :	Most annual grass weeds and certain broadleaves. Efficacy fair on yellow nutsedge, fair to poor on wild cane.
Application :	Pre-plant incorporated, pre-emergence, or very early post-emergence.

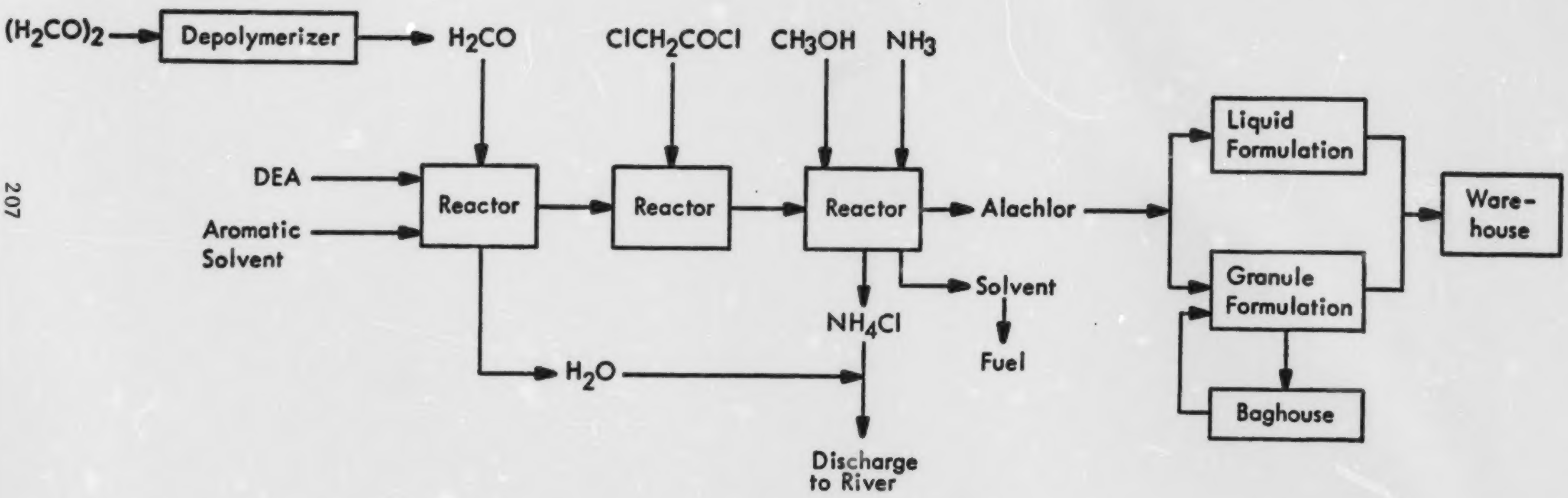

$(H_2CO)_2$
Depolymerizer
H_2CO
$ClCH_2COCl$
CH_3OH
NH_3
DEA
Aromatic Solvent
Reactor
Reactor
Reactor
Alachlor
Solvent
Fuel
NH_4Cl
H_2O
Discharge to River
Liquid Formulation
Granule Formulation
Baghouse
Ware-house

Figure 26 - Production and Waste Schematic for Alachlor[1/]

Used alone, or in combination with certain other herbicides, broadcast or banded. Applied by ground or air equipment.

Rates of Application : 2-4 lb AI/acre for broadcast treatment.

Frequency : Once per season.

Time of Application : Spring, at planting time of target crops.

Estimated Distribution : (All figures in millions of pounds AI/year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
24.0	None	3.0	21.0

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

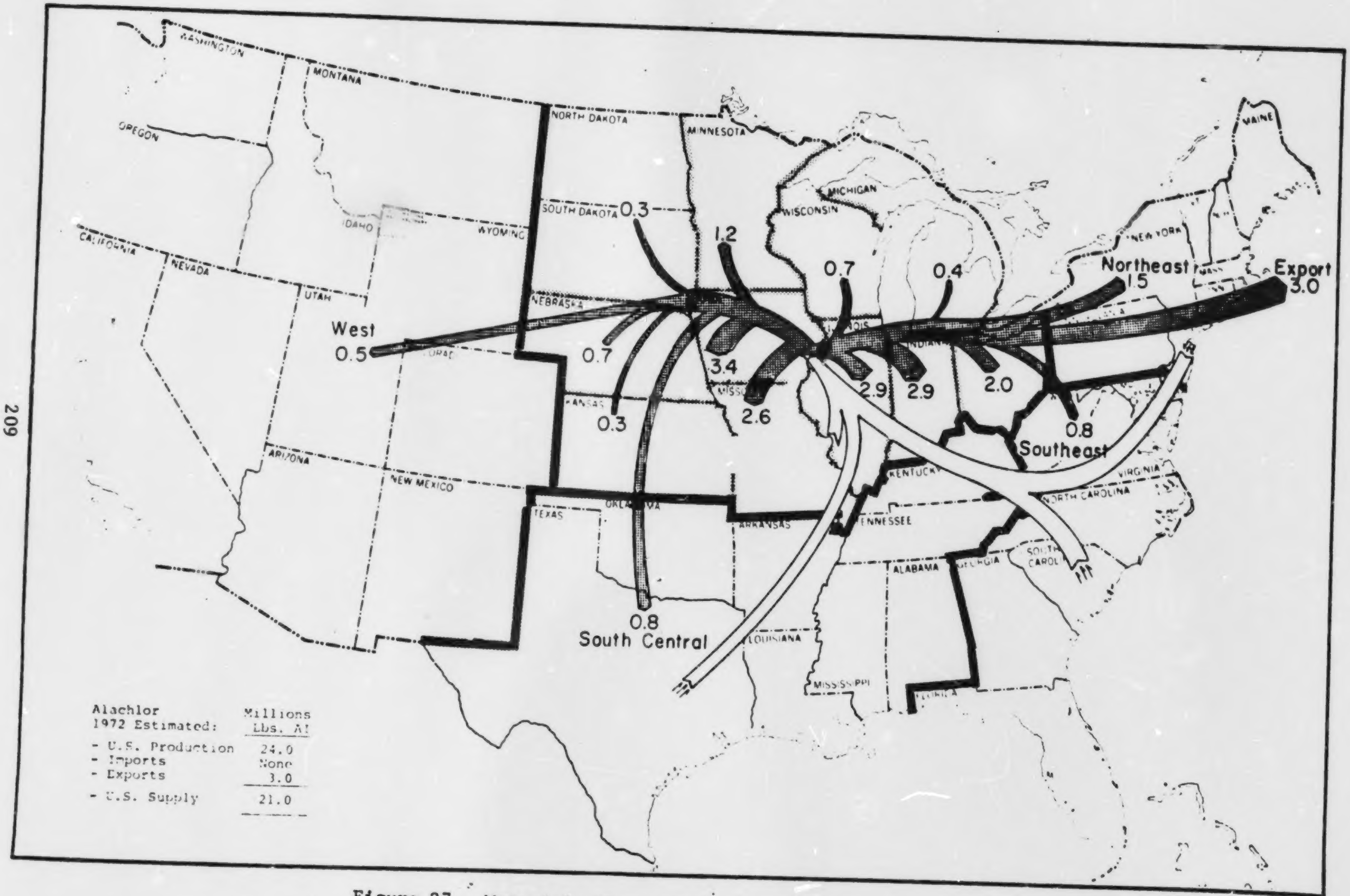
Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	1.5				1.5
SE	0.8				0.8
NC	17.4				17.4
SC	0.8				0.8
W	0.5				0.5
Totals	21.0				21.0

A materials flow diagram for alachlor is shown in Figure 27.

F. Alternatives

Chemicals : Propachlor (Ramrod), butylate (Sutan), chloramben (Amiben); trifluralin (Treflan); vernolate (Vernam); others.

Nonchemical : Mechanical removal of weeds by cultivation, hoeing or pulling weeds by land; changing crop rotation, planting dates, etc. None of these measures are entirely satisfactory on grass weeds. All of them would be more expensive than herbicides, except in rather weed-free fields.


WASHINGTON
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
MISSOURI
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
INDIANA
ILLINOIS
NEW YORK
MASS
MAINE
VIRGINIA
NORTH CAROLINA
SOUTH CAROL
West
0.5
0.3
0.7
0.3
1.2
3.4
2.6
0.7
2.9
2.9
0.4
2.0
0.8
Southeast
Northeast
1.5
Export
3.0
0.8
South Central

Alachlor 1972 Estimated:	Millions Lbs. AI
- U.S. Production	24.0
- Imports	None
- Exports	3.0
- U.S. Supply	21.0

Figure 27 - Materials Flow Diagram for Alachlor, 1972

G. Environmental Impact Potential

Mammalian Toxicity : The mammalian toxicity of alachlor is low. It is slightly toxic to laboratory animals by the oral and dermal routes, relatively non-toxic by inhalation. However, the chemical is severely irritating to eyes, nose, throat and skin, and may cause allergic skin reactions. The 4 lbs./gal. EC formulation therefore carries the signal word "Danger" on the label. No data on the chronic toxicity (2-year feeding tests) are available as yet. No cumulative toxic effects have been reported.

Residue tolerances ranging from 0.2-0.75 ppm have been established.

Nontarget Organisms : Alachlor is relatively non-toxic to fishes and birds. Its toxicity to lower aquatic organisms and soil organisms is not known. Based on the results of studies on laboratory mammals, it is probably relatively non-toxic to wild mammals under field use conditions. Data on possible build-up in food chains are not available.

Environment : Alachlor is adsorbed by soil colloids. It is degraded in the soil by biological as well as by chemical processes. Alachlor is not persistent, it is usually dissipated within 2-3 months after application. Carry-over of residues to the next season has not been a problem. Surface-exposed residues may be subject to volatilization. Alachlor has a low propensity for leaching, but may be transported away from treated fields by surface runoff or with solids through soil erosion.

Evaluation : Alachlor may be severely irritating to operators handling it. It may produce allergic skin reactions. No other serious human health hazards have been attributed to its use to this date. Data on possible effects on nontarget organisms or build-up in food chains are incomplete at this time.

CASE STUDY NO. 12 ATRAZINE

A. Product Description

Chemical Name: 2-Chloro-4-ethylamino-6-isopropylamino-s-triazine

Trade Names: G-30027, AAtram, AAtrex, Atranex, Fenamine, Fenatrol, Gesaprim, Primatol A

Pesticide Class: Selective herbicide; Triazine

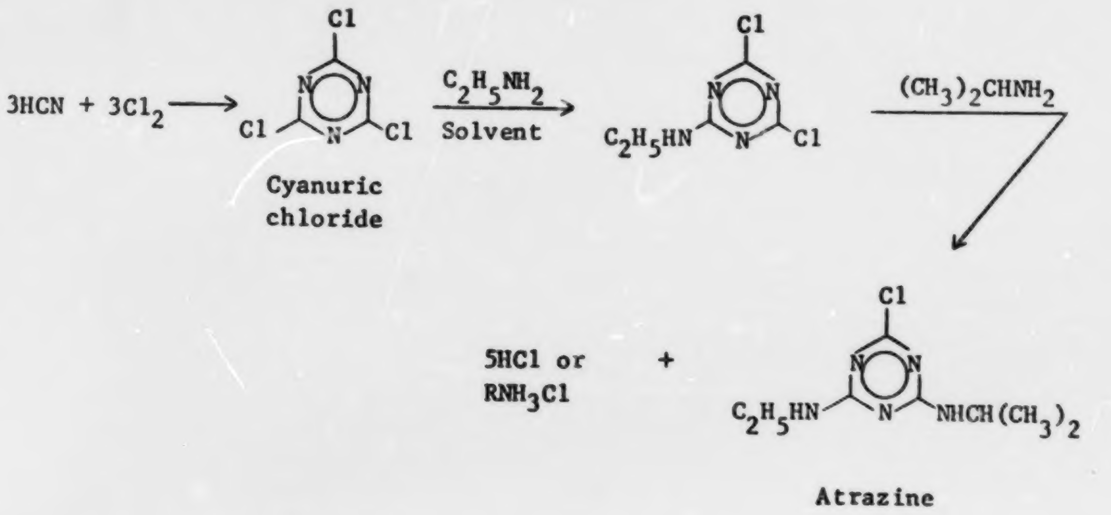
Properties: Solid; nearly insoluble in water; low toxicity; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity (mm lb/yr)	Estimated 1972 Production
Ciba-Geigy Corp.	St. Gabriel, Louisiana	200 million lb	95 million lb

C. Production Methods and Waste Control Technology

Information on production method and waste control technology for atrazine have been reported. The reaction chemistry is:


3HCN + $3Cl_2$
Cl
Cl
Cl
N
N
N
Cyanuric chloride
$C_2H_5NH_2$
Solvent
C_2H_5HN
$(CH_3)_2CHNH_2$
5HCl or
RNH_3Cl
+
$NHCH(CH_3)_2$
Atrazine

A production and waste schematic for atrazine is shown in Figure 28.

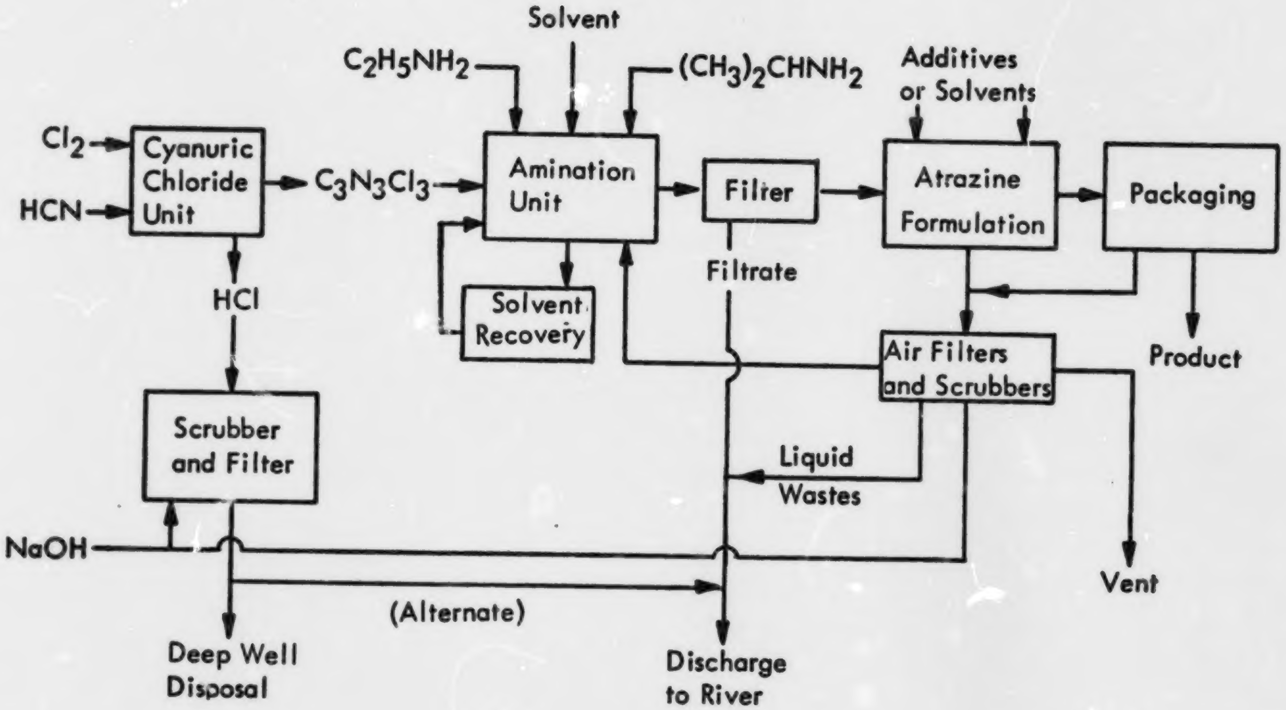

Solvent
$C_2H_5NH_2$
$(CH_3)_2CHNH_2$
Additives or Solvents
Cl_2
HCN
Cyanuric Chloride Unit
$C_3N_3Cl_3$
Amination Unit
Filter
Atrazine Formulation
Packaging
HCl
Solvent Recovery
Filtrate
Air Filters and Scrubbers
Product
Scrubber and Filter
Liquid Wastes
NaOH
Vent
(Alternate)
Deep Well Disposal
Discharge to River

Figure 28 - Production and Waste Schematic for Atrazine[1]

There is 1 lb. effluent to 1 lb. atrazine produced--mostly NaCl. Liquid wastes from cyanuric chloride production go to deep well disposal (after pH adjustment and filtration). The liquid wastes go to the river. The sanitary wastes are chlorinated and then sent to the river. The solid wastes (bag wrappers, car lining materials, etc.) are disposed of by commercial operators in landfills not located at the plant site. The formulation and packaging areas are controlled by baghouses and wet scrubbers and atmospheric monitors re used. There is no leakage problem. Packaging material is burned. Atrazine is manufactured by a continuous process in equipment used mostly for atrazine, but which can also be used for some other triazines.

D. Formulation, Packaging, and Distribution

Formulations are 80% wettable powder packaged in 5 lb. multi-walled bags and a 4 lb./gal. flowable concentrate available in 1- and 5-gallon jugs. Both are shipped by rail. Atrazine is also formulated in combination with several other herbicides.

E. Use Patterns

General : Atrazine leads all other herbicides in the U.S. in volume of use. It has an unusually large margin of selectivity for corn, this country's leading field crop. Several other triazine herbicides have been developed for the same use patterns as atrazine, but the volume of atrazine exceeds that of all other triazine herbicides combined by a wide margin.

Action : Herbicide for the control of annual broadleaf and grass weeds, may be applied before or after emergence of weeds (and crops). Acts mainly through root absorption. Inhibits photosynthesis, may have additional effects. Selectivity is a function of the rate of application.

Target Crops : Major: Corn, sorghum, sugarcane.
Minor: Pineapples, macademia orchards, turf grasses, re-forestation; some non-selective uses.

Target Weeds : Many annual broadleaf and grass weeds. Efficacy fair on giant foxtail and yellow nutsedge, poor on fall panicum, wild cane.

Application : Preplant, pre-emergence, or postemergence. Used alone, with crop oil in postemergence application, or in combinations with certain other herbicides, broadcast or banded.

Applied by ground or air equipment.

Rates of Application : 2-4 Lbs. AI/acre on field crops;
1.2 Lbs. AI/acre for grasses grown for seed production;
up to 6.4 lbs AI/acre for use on pineapples;
10-40 lbs. AI/acre for nonselective uses on noncropland areas.

Frequency : Usually one, rarely two, applications per season.

Time of Application : Spring, around planting time of target crops.

Estimated Distribution : (All figures in millions of lbs. AI/year, 1972)

U.S. Production	Imports	Export	Domestic Consumption
95	Negl.	20	75

Domestic Use by Category and Geographic Region

Region	Agricultural	Industrial/ Commercial	Gov't * Agencies	Home & * Garden	Totals
NE	2.0	0.2			2.5
SE	5.0	0.3			5.5
NC	56.5	0.3			57.3
SC	7.0	0.5			7.7
W	1.5	0.4			2.0
Totals	72.0	1.7	0.3	1.0	75.0

* Too small to break out, apportioned and included in total distribution.

A materials flow diagram for atrazine is shown in Figure 29.

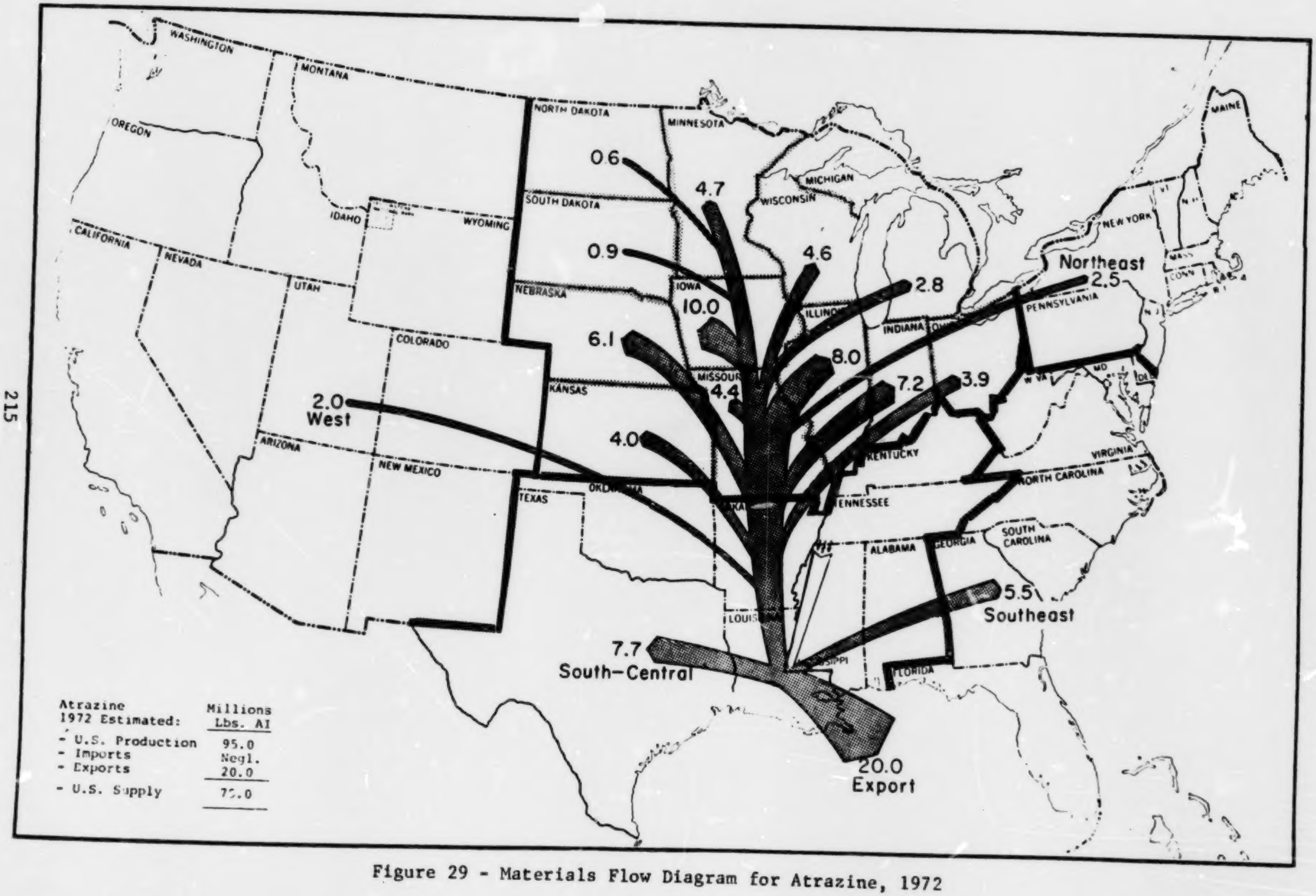

WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
SOUTH DAKOTA
WISCONSIN
MICHIGAN
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
IOWA
NEBRASKA
ILLINOIS
INDIANA
OHIO
COLORADO
MISSOURI
KANSAS
KENTUCKY
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
TENNESSEE
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
ALABAMA
GEORGIA
SOUTH CAROLINA
LOUISIANA
MISSISSIPPI
FLORIDA
NEW YORK
PENNSYLVANIA
MAINE
MASS
CONN
MD
DEL
N J
0.6
4.7
0.9
4.6
10.0
2.8
6.1
8.0
2.0
West
4.4
7.2
3.9
4.0
Northeast
2.5
5.5
Southeast
7.7
South-Central
20.0
Export
Atrazine
1972 Estimated:
Millions
Lbs. AI
- U.S. Production 95.0
- Imports Negl.
- Exports 20.0
- U.S. Supply 75.0

Figure 29 - Materials Flow Diagram for Atrazine, 1972

F. Alternatives

Chemicals : Cyanazine (Bladex); cyprazine (Outfox); simazine (Princep); alachlor (Lasso); propachlor (Ramrod); butylate (Sutan); 2,4-D; dicamba; others.

Nonchemical : Mechanical removal of weeds by tillage and cultivation, hoeing or pulling by hand; changing crop rotation, planting dates, etc. All of these measures would be much less efficient and effective, and considerably more expensive than herbicides.

G. Environmental Impact Potential

Mammalian Toxicity : In acute toxicity tests, atrazine was slightly toxic to laboratory mammals by the oral or dermal route or by inhalation. The 80% wettable powder formulation requires the signal word "Caution" on the label. In 2-year chronic toxicity tests, the no-effect level in the diet of rats was 100 ppm. Tolerances for residues of atrazine have been established for a number of crops, ranging from 0.25-15.0 ppm, 0.25 ppm for most commodities; 0.02 ppm in eggs, milk, meat fat and meat by-products of cattle, goats, hogs, horses, poultry and sheep.

Nontarget Organisms : Atrazine is relatively nontoxic to birds, wild mammals, and soil organisms, slightly toxic to fish, and moderately toxic to lower aquatic organisms. No data are available on its possible buildup in food chains. In laboratory tests[73] atrazine was nontoxic to insects by itself, but it substantially increased the toxicity of 12 different insecticides to Drosophila fruit flies, and of a smaller number of insecticides to two other insect species.

Environment : Atrazine is quite stable and may persist in the soil in sufficient concentration to cause injury to susceptible plants such as small grains, soybeans or alfalfa planted the following season. It is subject to degradation by microbial action as well as by nonbiological factors, including photodecomposition. In the soil, it is reversibly adsorbed on soil particles. Desorption appears to occur readily. Atrazine may

Environment continued : dissipate from treated areas by volatilization, but this does not take place to a significant extent under normal field conditions. However, the rate of leaching or surface run-off in water or on solids may be substantial, especially if heavy rainfalls follow soon (1-2 weeks) after application.

In the National Soils Monitoring Program, atrazine residues in the soil were found in 14% of 199 samples that were analyzed for atrazine residues selected because of their use histories.

Evaluation : No serious hazards to human health have been attributed to the use of atrazine as a herbicide to this date, even though the product has been used in very large volume in the U.S. for about 15 years.

Based on presently available information, the use of atrazine in accordance with label directions appears to pose little, if any hazard to terrestrial ecosystems outside the target area. Data on possible effects on lower aquatic organisms or buildup in food chains are inadequate to determine whether or not there may be hazards to aquatic ecosystems. The reported synergism of insecticide toxicity by atrazine underscores the need for more information in this regard, especially if the large volume of use and the persistence of atrazine are considered.

CASE STUDY NO. 13. BROMACIL

A. Product Description

Chemical Name: 5-Bromo-3-sec-butyl-6-methyluracil

Trade Names: Hyvar X, Hyvar X-L

Pesticide Class: Herbicide - weed and brush killer; uracil herbicide

Properties: Crystalline solid melting at 158-159°C; water solubility, 815 ppm at 25°C; moderately soluble in acetone, strong aqueous bases, and ethyl alcohol; sparingly in hydrocarbons

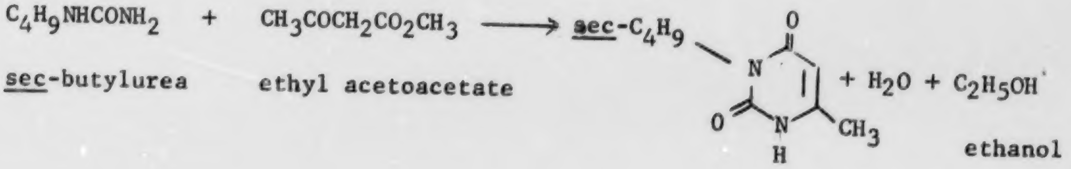
B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
E. I. du Pont de Nemours & Co., Inc.	La Porte, Texas	Est. 20 million lb/yr uracils	4 million lb

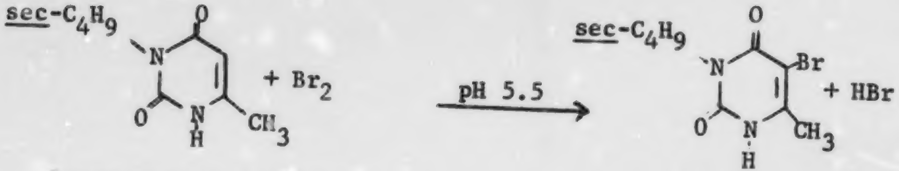
C. Production Methods and Waste Control Technology

Bromacil is a relatively new herbicide (still under patent) whose use is growing; the duPont company declined to reveal details about its production. The reaction chemistry is believed to be approximately as follows:

$$\underset{\underline{\text{sec}}\text{-butylamine}}{\underline{sec}\text{-}C_4H_9NH_2} + \underset{\text{phosgene}}{COCl_2} + \underset{\text{ammonia}}{NH_3} \longrightarrow \underset{\underline{\text{sec}}\text{-butylurea}}{C_4H_9NHCONH_2} + 2HCl$$



3-sec-butyl-6-methyluracil



3-sec-Butyl-6-methyluracil

Bromacil

A tentative production and waste control schematic is shown in Figure 30. The major portion of raw materials were said to be shipped to La Porte from the East Coast (primarily in tank cars), but some were obtained locally. No solid wastes are generated and no significant quantities of chemicals are recycled. Liquid wastes are disposed of by either biological treatment (followed by discharge), incineration, or deep sea dumping.

Terbacil is probably made in the same equipment.

D. Formulation, Packaging, and Distribution

Bromacil is primarily a nonselective, nonagricultural herbicide and is most used by itself or is tank-mixed with other herbicides. Most of the technical bromacil is formulated at La Porte. DuPont formulates bromacil in two forms: an 80% WP and 2 lb bromacil per gallon (as lithium salt). The 80% WP is packaged in 50-lb fiber drums and 4-lb bags. Bromacil liquid (2 lb/gal) is available in 1-, 5-, and 30-gal. containers. Bromacil is also formulated as wettable powders in combination with diuron.

Bromacil is sold in practically all parts of the United States, almost exclusively under the DuPont label. Only a small amount, much less than 10%, is used in formulations under other labels. Exports are estimated in the range of 0.5 to 1 million pounds per year.

E. Use Patterns

General : Bromacil belongs to a group of uracil chemicals whose herbicidal potential has been developed during the last 10 years. Most uracils in this group (including bromacil) are highly effective, broad-spectrum herbicides. Bromacil has been in commercial use since the mid-1960's, and its use volume is still on the increase. Its principal use is in the field of industrial and commercial vegetation control; agricultural uses are relatively minor.

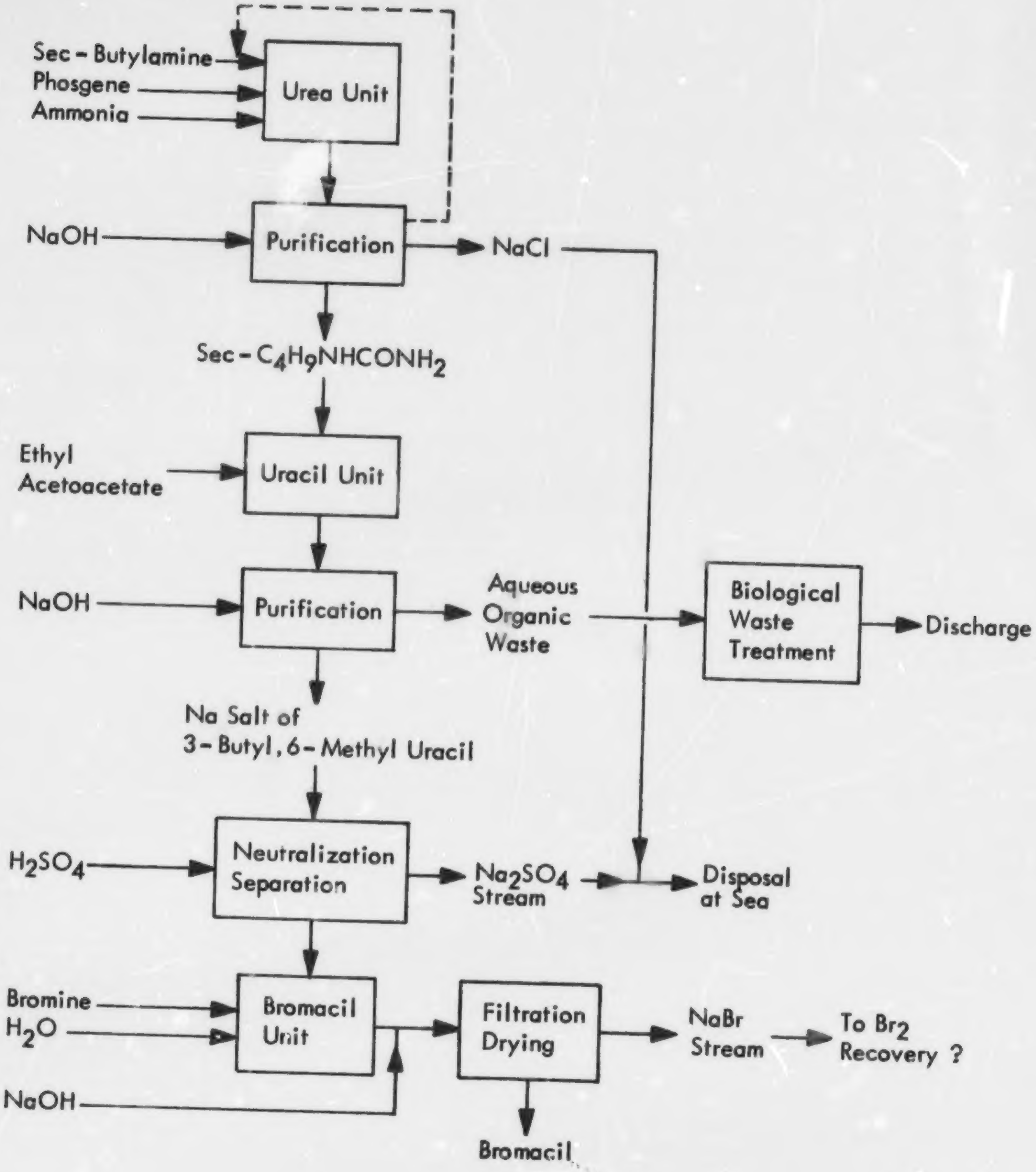

Sec-Butylamine
Phosgene
Ammonia
Urea Unit
NaOH
Purification
NaCl
Sec-$C_4H_9NHCONH_2$
Ethyl Acetoacetate
Uracil Unit
NaOH
Purification
Aqueous Organic Waste
Biological Waste Treatment
Discharge
Na Salt of 3-Butyl, 6-Methyl Uracil
H_2SO_4
Neutralization Separation
Na_2SO_4 Stream
Disposal at Sea
Bromine
H_2O
NaOH
Bromacil Unit
Filtration Drying
NaBr Stream
To Br_2 Recovery ?
Bromacil

Figure 30 - Production and Waste Schematic for Bromacil

Action : Broad-spectrum, soil-applied herbicide, selective at lower rates. Inhibits photosynthesis.

Target Crops : Noncropland for weed and brush control. Pineapple, citrus (selective use).

Target Weeds : Annual grass and broadleaf weeds at lower rates; kills all vegetation, including deep-rooted perennial weeds, grasses (including johnsongrass) and brush at higher rates.

Application : Pineapple, broadcast at planting time or directed interline spray to established plantings; citrus, band or broadcast under and between trees.

On noncropland, broadcast or spot treatment.

Always applied by ground equipment.

Rates of Application: 1.6-4.8 lb AI/acre on pineapple;
3.2-6.4 lb AI/acre on citrus.
For general vegetation control, 5-24 lb AI/acre.

Frequency : 1-2 applications per crop on pineapple; 1 per year on citrus; one or more applications per year for general vegetation control.

Time of Application: Variable, throughout vegetation season.

Estimated Distribution : (All figures in millions of lb AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
4.0	None	1.0	3.0

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industr. Comm.	Subtotals	Government Agencies	Home and Garden	Totals
NE	--	0.2	0.2			
SE	Small	0.5	0.5			
NC	--	0.4	0.4			
SC	--	0.8	0.8			
NW	--	0.2	0.2			
SW	0.4	0.2	0.6			
Totals	0.4	2.3	2.7	0.3[a]	None	3.0

---

[a] Too small to break out by regions.

A materials flow diagram for bromacil is shown in Figure 31.

F. Alternatives

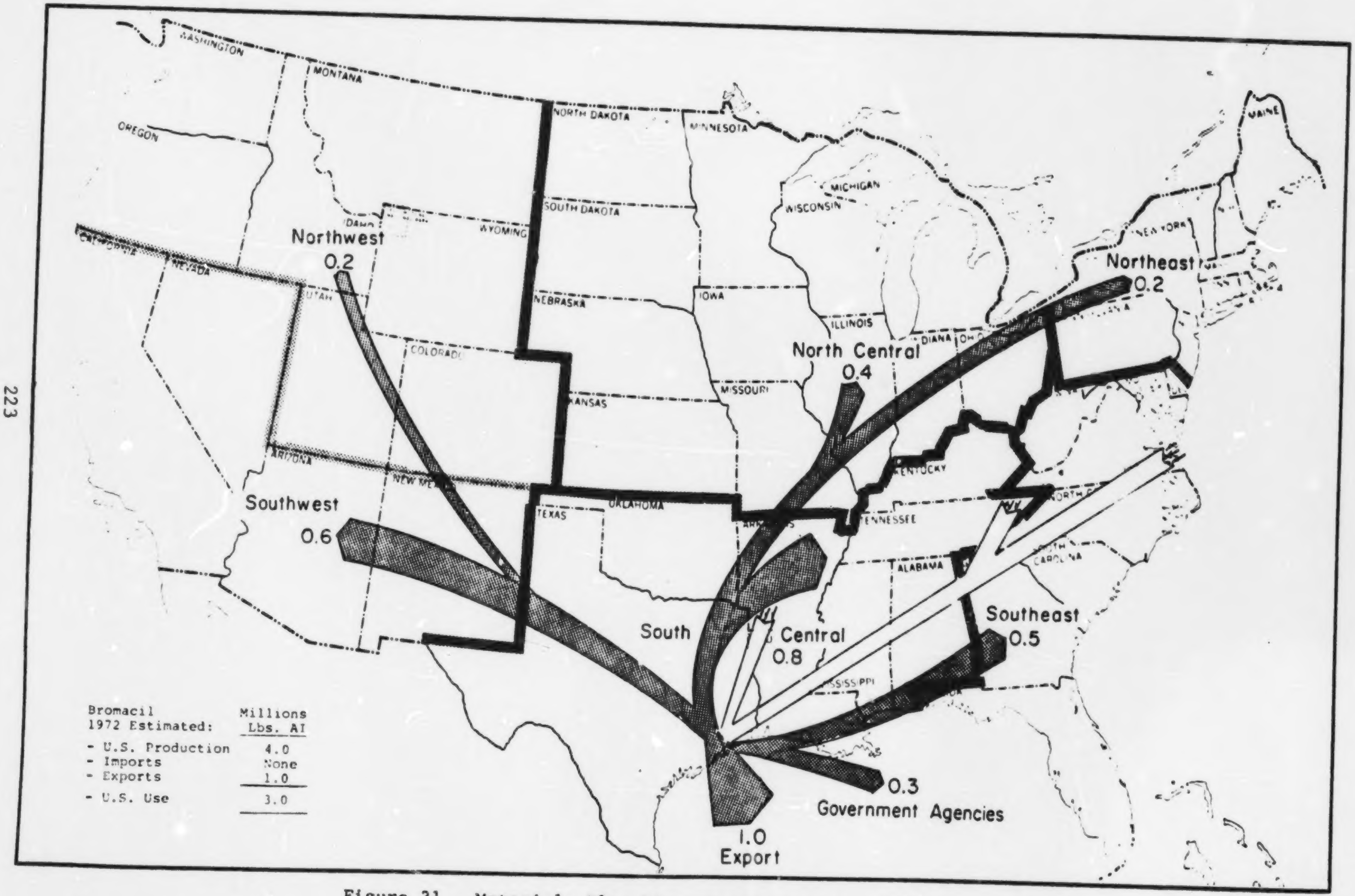
Chemicals : For selective uses: diuron; other herbicides. For nonselective uses: diuron; simazine; chlorates-borates; TCA; many other herbicides and herbicide combinations.

Nonchemical : In pineapple and citrus plantings (the only crops for which bromacil is currently registered for selective weed control), mechanical removal of weeds would be possible in most instances, although probably at greater expense and inconvenience than by use of herbicides.

Control of unwanted vegetation on industrial and commercial premises, along railroads, etc. is not feasible without the use of chemicals. Inorganic chemicals were used for these purposes (and are still in use today) until more effective organic herbicides were developed after World War II.

G. Environmental Impact Potential

Mammalian Toxicity : In acute toxicity tests, bromacil was relatively nontoxic to laboratory animals via the oral and dermal routes. It may be moderately irritating to eyes, nose, throat and skin, but there are no reports of induction or skin sensitization. The signal word "Caution" is required for the labeling of


Northwest
0.2
Southwest
0.6
North Central
0.4
Northeast
0.2
South
Central
0.8
Southeast
0.5
0.3
Government Agencies
1.0
Export
WASHINGTON
OREGON
MONTANA
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
ALABAMA
MISSISSIPPI
NORTH CAROLINA
SOUTH CAROLINA
NEW YORK
MAINE

Bromacil 1972 Estimated:	Millions Lbs. AI
- U.S. Production	4.0
- Imports	None
- Exports	1.0
- U.S. Use	3.0

Figure 31 - Materials Flow Diagram for Bromacil, 1972

bromacil formulations. In 2-year chronic toxicity tests, the no-effect level in the diet was 250 ppm for rats, 1250 ppm for dogs. Tolerances of 0.1 ppm have been established for bromacil residues in or on citrus fruits and pineapple.

Nontarget Organisms : Bromacil is relatively nontoxic to birds. It is slightly to moderately toxic to fishes. No data are available on its toxicity to wild mammals, soil organisms or lower aquatic organisms, nor on its possible build-up in food chains.

Environment : Bromacil is moderately persistent in the soil. Rate of degradation depends on rainfall, soil properties, soil environment, microbial activity, and other factors. In one test, the half-life of bromacil applied at the rate of 4 lb AI/acre was about 5-6 months. No data are available on the extent to which microbial activity and/or nonbiological factors may contribute to the degradation of bromacil in the soil. It is subject to leaching and, based on laboratory studies and its water solubility, may also be expected to be transported away from target areas as a solute in surface runoff water, or adsorbed on soil solids.

Evaluation : There are no indications of serious hazards to human health or to terrestrial ecosystems outside of target areas from the use of bromacil for weed or vegetation control in accordance with label directions. Data on the possible effects of bromacil on aquatic organisms and on its possible build-up in food chains are not available and, consequently, possible hazards in these fields cannot be estimated at this time.

CASE STUDY NO. 14. 2,4-D

A. Product Description

Chemical Name: 2,4-Dichlorophenoxyacetic acid, its amine salts and esters.

Trade Names: A dozen or more

Pesticide Class: 2,4-D is a selective herbicide used against broadleaf plants.

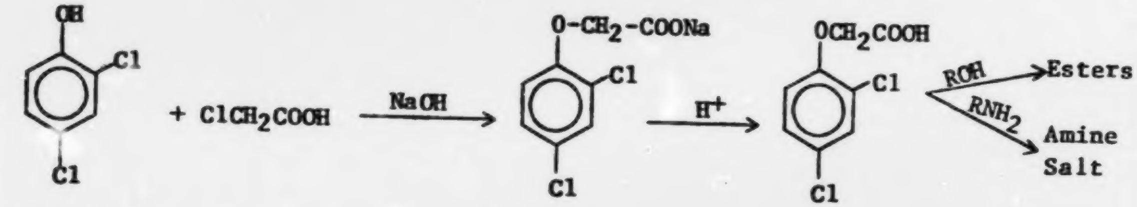
Properties: Solid; salts are water-soluble, acid and esters nearly insoluble; moderately toxic; nonpersistent.

B. Manufacturers

Name	Plant Location	Plant Capacity	Est. 1972 Prod.
Dow Chemical Company	Midland, Michigan	45-50 MM lb/yr	40-45 MM lb
Rhodia Inc., Chipman Div.	Portland, Oregon	5-10 MM lb/yr	5 MM lb
Transvaal Chemical	Jacksonville, Arkansas	5-10 MM lb/yr	5 MM lb

C. Production Methods and Waste Control Technology

Information on Dow's production and waste control technology for 2,4-D has been reported.[1] The reaction chemistry is:



Dichlorophenol **Chloroacetic acid** **2,4-D Sodium salt** **2,4-D**

Dow Chemical Company's production process (Figure 32) is semicontinuous. Raw materials are: salt from brine wells in the area; benzene from nearby Bay City by pipeline; acetic acid and acetic anhydride by rail. The primary by-products, the inorganic chlorides, are extensively recycled, and side-reaction product 2,6-dichlorophenol is converted to pentachlorophenol.

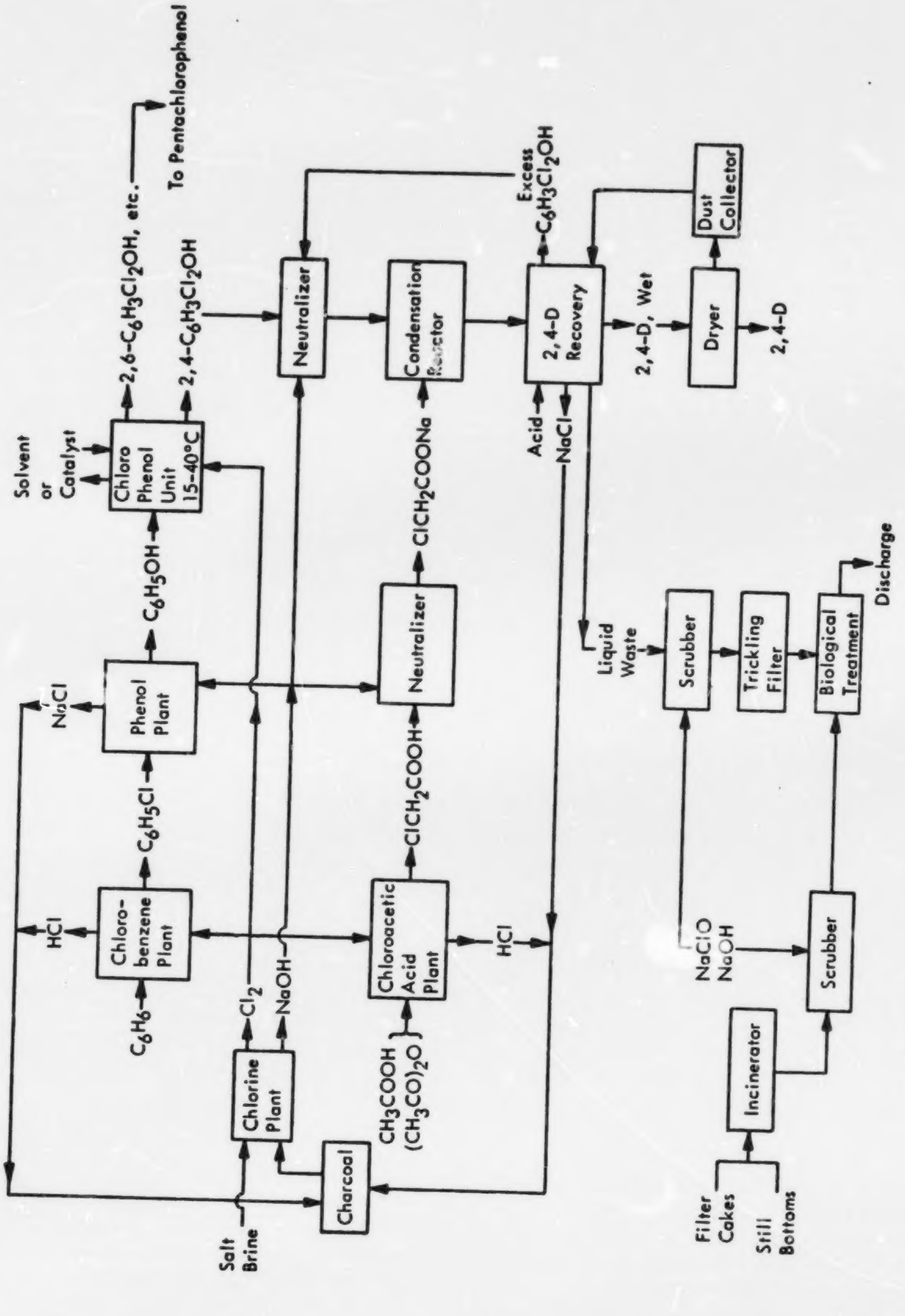

Salt Brine
Chlorine Plant
Cl2
NaOH
Charcoal
C6H6
Chloro-benzene Plant
HCl
C6H5Cl
Phenol Plant
NaCl
C6H5OH
Chloro Phenol Unit 15-40°C
Solvent or Catalyst
2,6-C6H3Cl2OH, etc.
To Pentachlorophenol
2,4-C6H3Cl2OH
CH3COOH
(CH3CO)2O
Chloroacetic Acid Plant
HCl
ClCH2COOH
Neutralizer
ClCH2COONa
Neutralizer
Condensation Reactor
2,4-D Recovery
Acid
NaCl
Excess C6H3Cl2OH
2,4-D, Wet
Dryer
Dust Collector
2,4-D
Liquid Waste
Scrubber
Trickling Filter
Biological Treatment
Discharge
NaClO
NaOH
Scrubber
Incinerator
Filter Cakes
Still Bottoms

Figure 32 - Production and Waste Schematic for 2,4-D (Dow Chemical)1/

Dusts are collected and recycled. Liquid wastes are chemically treated, passed through a special trickling filter and then to a biological waste treatment plant. Solid wastes, still bottoms, etc., are incinerated; the combustion gases are scrubbed, the water chemically treated, and sent to the bio-waste plant.[1/]

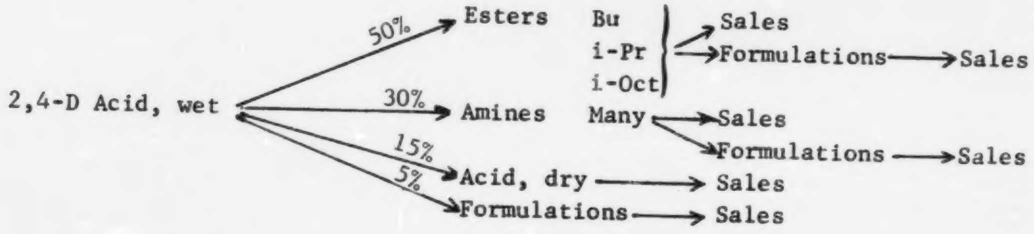
Chipman has revealed little of their production process.[1/] Chlorine is generated on site and the process is presumably much like that of Dow. The waste treatment facilities center on a charcoal absorption plant.[1/]

Transvaal began operation in 1972 of the phenoxy herbicide plant formerly operated for many years by Hercules, Inc. Total production capacity for 2,4-D, 2,4,5-T, Silvex and MCPA is believed to be about 10 million lb/year. All raw materials (including chlorine) are purchased. Wastewater discharges are minimized by use of a floculation/settling pond and extensive recirculation, and are monitored by the city and state.

D. Formulation, Packaging and Distribution

2,4-D is used primarily in the form of amine salts or high-volatile or low-volatile esters, formulated as liquid concentrates. A variety of different brands and concentrations are on the market. Granular formulations are also available, but are not used much.

Dow sells 40-60 formulations in addition to technical. The product mix is approximately as follows:



Perhaps 50% of total production is shipped in tank cars (mostly 8,000-gal., some 4,000-gal.) and the remainder in bags and drums. Containers for esters and amines range from tank cars to 5-gal. cans. Formulated products usually go to smaller containers and dry products to 50-lb bags. Over 250,000 5-gal. cans are packaged per year.

Most of the 2,4-D sales are in the grain states. Sales are made primarily through other companies such as AmChem, American Oil, Guth and Farmland Industries.

Chipman does not retail 2,4-D. About 50% of production is sold as acid, with formulation done at Portland and outside. Amine salts and the octyl and butyl esters are formulated in Portland, in Chipman facilities in North Kansas City and St. Paul, and by outside formulators. The 2,4-D products are shipped in tanks (rail and truck) down to 1-gal. cans.

Transvaal does not retail 2,4-D but wholesales instead to a number of national distributors and larger buyers. Sales are well distributed geographically except that very little is sent west of the Rocky Mountains.

E. Use Patterns

General : 2,4-D is one of the most inexpensive selective herbicides. It provides very economical control of target weeds.

Action : Selective herbicide for control of broadleaf weeds and brush. Interferes with the normal growth processes of many dicotelydenous plants. Exact mode of action not known despite numerous studies.

Target crops : Small grains; corn; sorghum; sugarcane; rice; pastures and rangeland; lawn and turf; additional minor crop uses; uses on noncropland.

Target weeds : Many broadleaf weeds, brush.

Application : Primarily post-emergence spraying; some pre-emergence use on corn; some use in mulches in lawn and garden market. Broadcast application by ground or air. For brush control, often used in combination with 2,4,5-T or other herbicides.

Rates of application : 0.25 to 2.0 lb AI/acre against herbaceous weeds on cropland; 1.0 up to 16 lb (mostly 3-4 lb) AI/acre on noncropland and against woody weeds.

Frequency : For most uses, one application per season. Sugarcane may receive three or four treatments per year.

Time of application : Late spring and early summer, after crops and weeds emerge.

Estimated distribution : (All figures in millions of lb AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
55	Negl.	7	48

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industr. Comm.	Government Agencies	Subtotal	Home and Garden[a]	Totals
NE	1.0	0.9	0.1	2.0		
SE	2.5	1.2	0.4	4.1		
NC	19.0	1.5	0.6	21.1		
SC	5.0	1.5	0.5	7.0		
NW	6.4	0.3	1.1	7.8		
SW	2.1	0.6	0.3	3.0		
Totals	36.0	6.0	3.0	45.0	3.0	48.0

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a/ Geographic distribution not known.

A materials flow diagram for 2,4-D is shown in Figure 33.

F. Alternatives

Chemicals : Other phenoxy-type herbicides including MCPA, 2,4,5-T; dicamba (Banvel); picloram (Tordon); silvex.

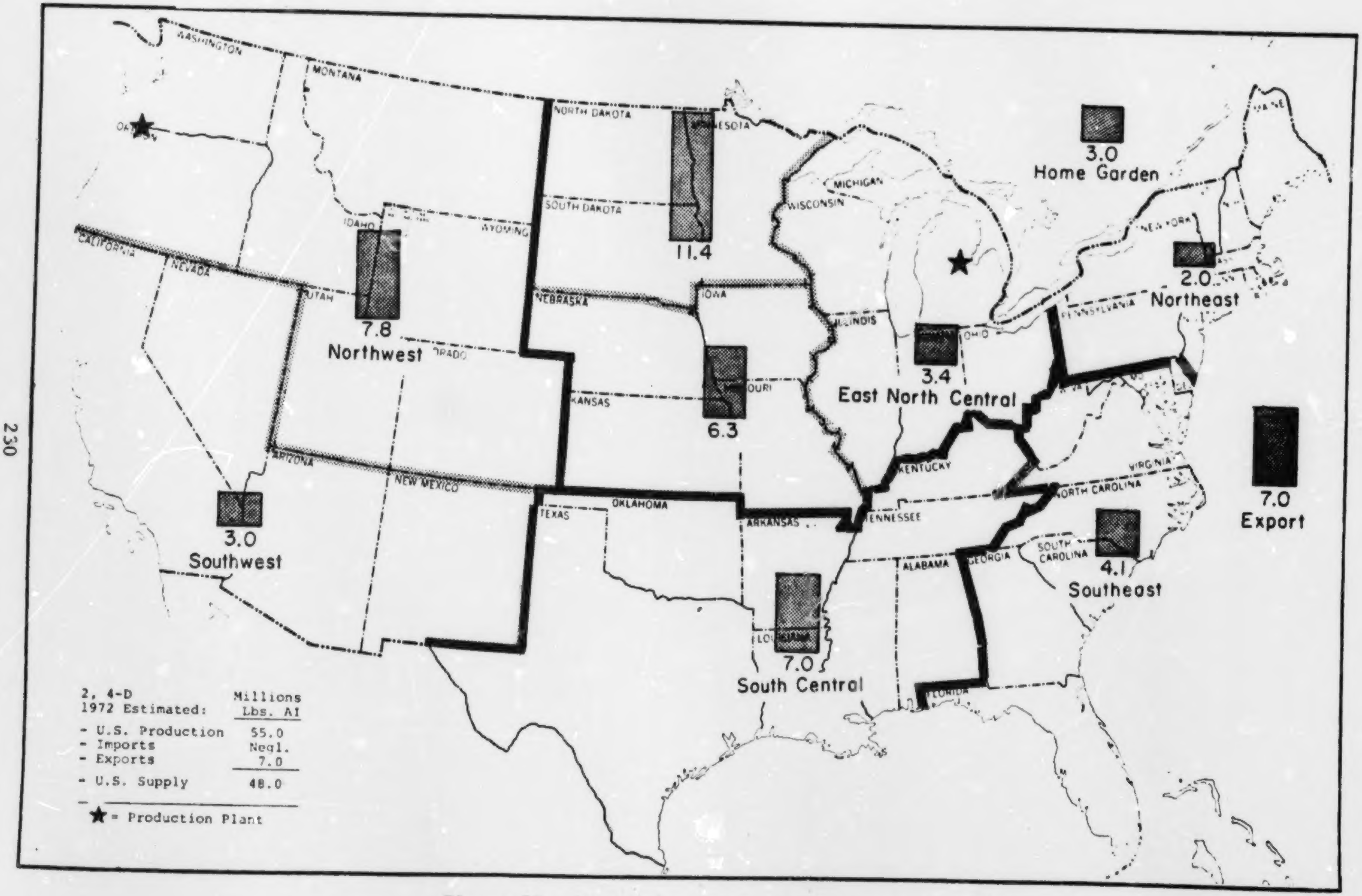
Nonchemical : Mechanical removal of weeds by cultivation, hoeing, etc.; changing crop rotation, planting dates, etc.; none of these economically attractive.

G. Environmental Impact Potential

Mammalian Toxicity : 2,4-D is moderately toxic to laboratory mammals via the oral and dermal route, and only slightly toxic by inhalation. Most commercial 2,4-D formulations fall within the "slightly toxic" category and require only the signal word "Caution" on their labels. Some formulations may be irritating to eyes, nose, throat and/or skin.

In chronic toxicity tests, no-effect levels in the diets of rats and dogs were of the order of 500-1,200 ppm. Tolerances for 2,4-D residues have been established for a number of crops, ranging from 0.5-20.0 ppm, 5.0 ppm being the most common level.

No cumulative toxic effects have been reported for 2,4-D.


WASHINGTON
OREGON
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
KANSAS
MISSOURI
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
OHIO
KENTUCKY
TENNESSEE
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
3.0
Home Garden
2.0
Northeast
3.4
East North Central
7.0
Export
4.1
Southeast
7.0
South Central
11.4
6.3
7.8
Northwest
3.0
Southwest

2, 4-D 1972 Estimated:	Millions Lbs. AI
- U.S. Production	55.0
- Imports	Negl.
- Exports	7.0
- U.S. Supply	48.0

★ = Production Plant

Figure 33 - Materials Flow Diagram for 2,4-D, 1972

Nontarget Organisms : 2,4-D is moderately toxic to some species of fish under laboratory conditions; slightly toxic to lower aquatic organisms, birds, and wild mammals; and practically non-toxic to soil organisms. It does not build up in food chains.

High-volatile ester formulations of 2,4-D may cause injury to nearby susceptible plants through volatilization. Label directions for use are designed to prevent this.

Environment : 2,4-D degrades rapidly in the environment after application. It is broken down by biological organisms as well as by sunlight and other non-biological factors. Soil residues generally disappear within 1-4 weeks. Volatilization and leaching rates vary for different 2,4-D derivatives and formulations; but the environmental mobility of intact 2,4-D is generally low due to the low persistence of the chemical.

Evaluation : The use of 2,4-D for weed control in accordance with label directions involves few if any known hazards to human health or to the environment. This statement is supported by the fact that 2,4-D has been in large-scale, large-volume commercial use worldwide for many years, with a good safety record, except for cases of damage to susceptible vegetation near target areas due to careless use, especially of high-volatile ester formulations.

The product's low cost might tend to invite unnecessary use. However, it is used primarily post-emergence rather than preventively, and overuse (excessively high rates) may damage desirable vegetation. These factors present built-in constraints against gross misuse.

CASE STUDY NO. 15. DIURON

A. Product Description

Chemical Name: 3-(3,4-Dichlorophenyl)-1,1-dimethylurea

Trade Names: Di-on, Diurex, Karmex

Pesticide Class: Selective herbicide; non-selective weed killer; urea herbicide

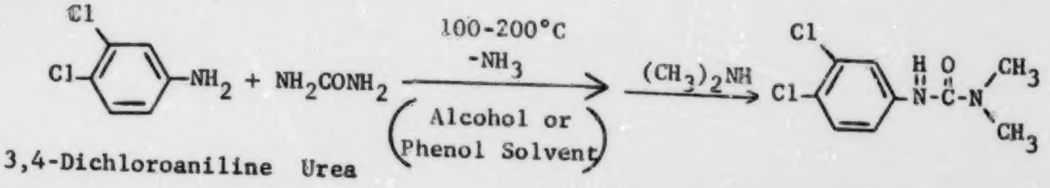
Properties: White crystals melting at 158-159°C. Solubility very low in hydrocarbons; only 42 ppm in water.

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
E. I. du Pont de Nemours & Co., Inc.	La Porte, Texas	Est. 30 million lb total ureas	6.5 million lb

C. Production Methods and Waste Control Technology

DuPont has been the only domestic producer of diuron, although the patents expired in the late 1960's and several foreign manufacturers exist.* DuPont declined to discuss details of their manufacturing process, but the reaction chemistry is believed to be approximately as follows:



A tentative production and waste schematic is shown in Figure 34. Raw materials were said to received primarily from the East Coast by tank car, but some are obtained locally and some via the Houston ship channel. Wastes are disposed of in treatment facilities that service the entire La Porte site, including incineration, biological treatment/discharge and deep sea dumping.

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* Crystal Chemical Company of Texas may produce diuron in 1974.

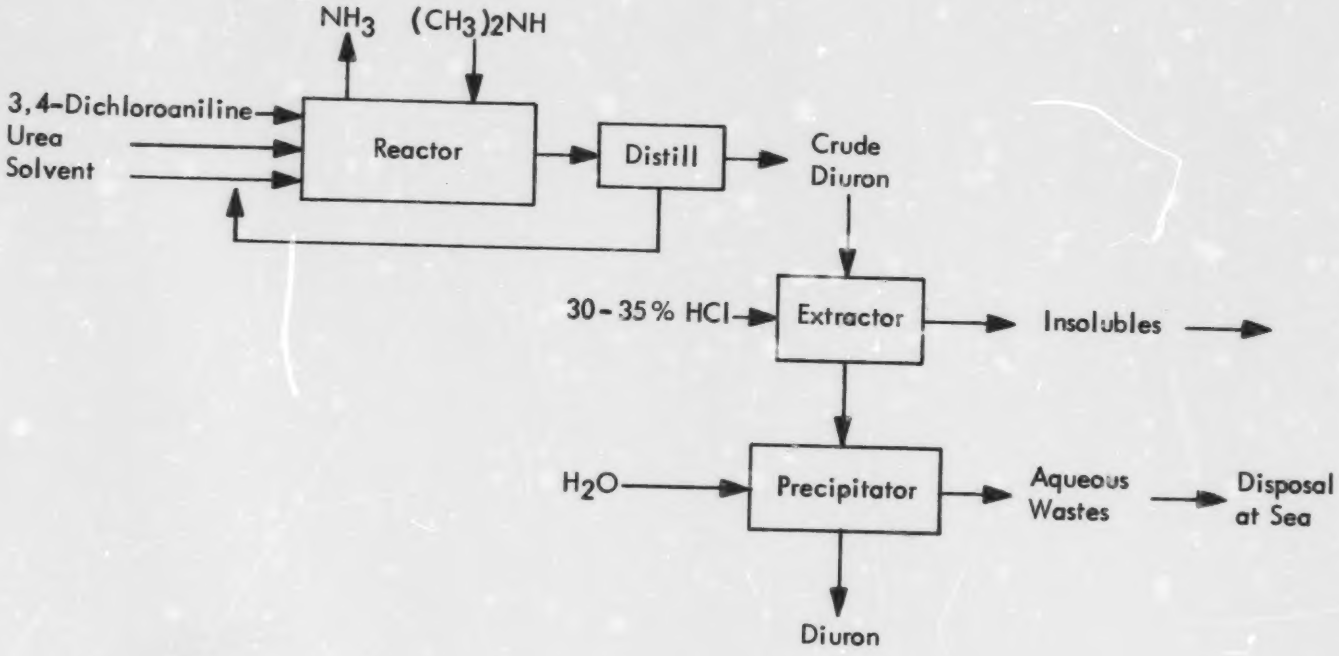

NH$_3$
(CH$_3$)2NH
3,4-Dichloroaniline
Urea
Solvent
Reactor
Distill
Crude Diuron
30-35% HCl
Extractor
Insolubles
H$_2$O
Precipitator
Aqueous Wastes
Disposal at Sea
Diuron

Figure 34 - Production and Waste Schematic for Diuron

D. Formulation, Packaging, and Distribution

Technical diuron is formulated principally into a 80% WP and, in lesser amounts, into a 2.8 lb/gal. flowable concentrate, or 10% granules. Shipment of the technical solid and 80% WP diuron is in drums or bags by rail or truck. The granular formulation is not marketed by DuPont. Diuron may also be formulated in combination with other herbicides. Diuron usage is fairly concentrated in the southern tier of states.

E. Use Patterns

General : Diuron was one of the first substituted urea herbicides to be developed. It is still the leading product in this group today in terms in volume. Diuron has been in commercial use in the U.S. for over 20 years for farm as well as for nonagricultural weed control. Nonfarm uses account for the larger use volume today.

Action : Broad-spectrum, soil-applied herbicide; selective at lower rates. Controls susceptible weed seedlings. Absorbed through the root system, to a much lesser extent through stems and foliage. Diuron strongly inhibits the Hill reaction, indicating photosynthesis inhibition in vivo.

Target Crops : Noncropland, for complete vegetation control. Cotton, sugarcane, pineapple, many other field, vegetable and fruit crops. Registered for use on about 40 crops.

Target Weeds : Annual grass and broadleaf weeds if used as a selective herbicide. General vegetation killer at higher rates. Works best on seedling weeds.

Application : For general vegetation control, broadcast or spot treatment by ground equipment. For selective weed control, applied pre-emergence, or as directed post-emergence spray between rows. Used mostly by itself, sometimes followed by another post-emergence herbicide. No air applications.

Rates of Application : For selective weed control, 0.5 to 2.0 lb AI/acre, up to 6.4-8.0 lb AI/acre. For general vegetation control, 4-16 lb AI/acre for control of annuals; 16-48 lb AI/acre for control of perennials.

Frequency : Once per season for selective weed control. As required, depending on climate, length of vegetation season, etc., for general vegetation control.

Time of Application : At planting time in selective weed control. Variable in general vegetation control.

Estimated Distribution : (All figures in millions of lb AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
6.5	0.7	0.5	6.7

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industr. Comm.	Subtotals	Government Agencies	Home and Garden	Totals
NE	0.1	0.3	0.4			
SE	0.2	0.8	1.0			
NC	Negl.	0.6	0.6			
SC	0.8	1.3	2.1			
NW	0.1	0.4	0.5			
SW	1.3	0.4	1.7			
Totals	2.5	3.8	6.3	0.4[a]	Negl.	6.7

---

[a] Too small to break out by regions.

A materials flow diagram for diuron is shown in Figure 35.

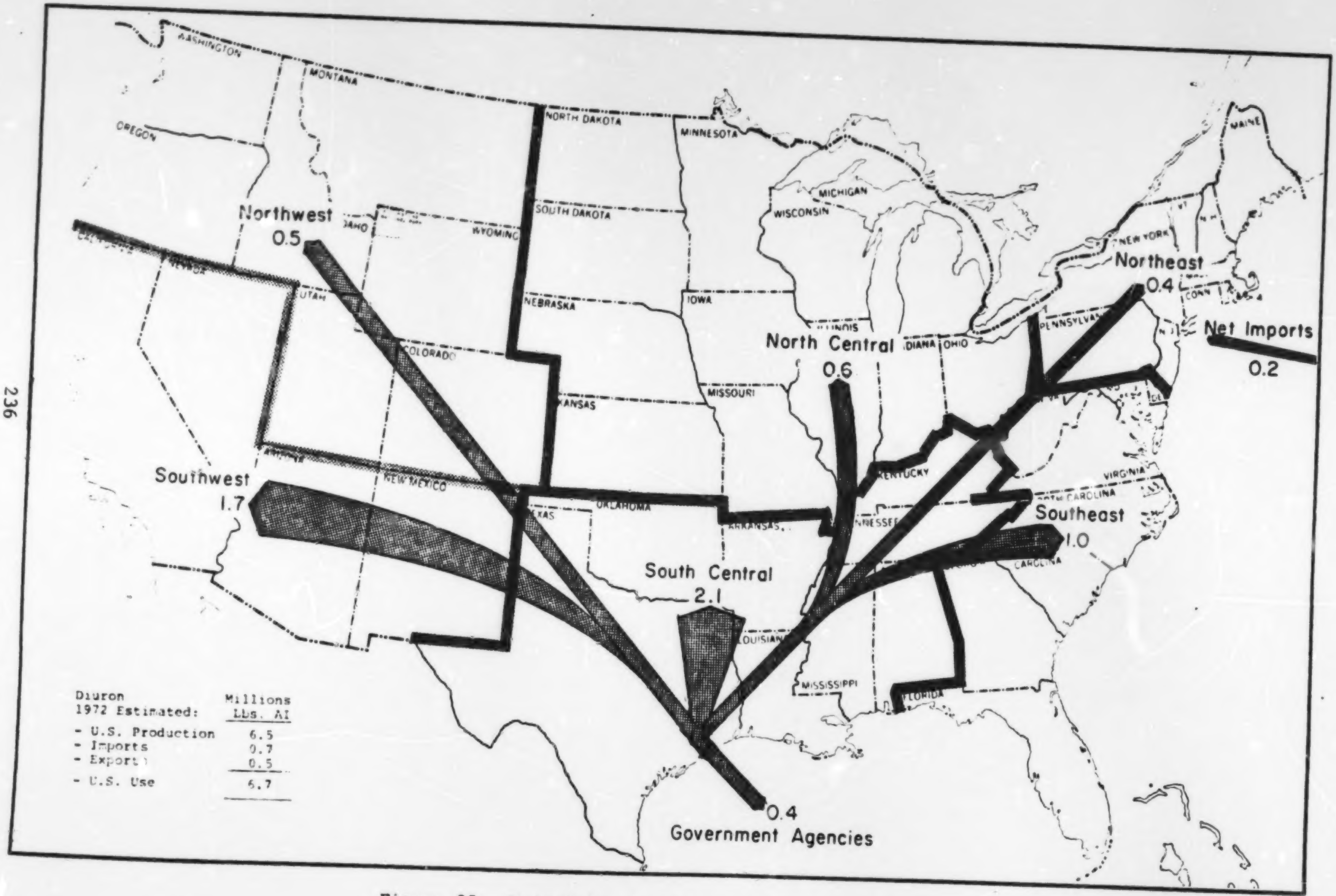
F. Alternatives

Chemicals : For selective uses: Fluometuron (Cotoran, Lanex); norea (Herban); prometryne (Caparol); DCPA (Dacthal); combinations of grass and broadleaf weed killers.

For nonselective uses: Bromacil (Hyvar); simazine (Princep); chlorates-borates; TCA; prometone (Pramitol); many other herbicides and herbicide combinations.

Nonchemical : Mechanical removal of weeds by tillage, cultivation, hoeing or pulling by hand or, in the case of agricultural uses, other farm management practices. None of these are as effective as the use of herbicides.

Nonselective removal of unwanted vegetation from right-of-ways, industrial sites, railroad yards, etc., is not feasible without the use of chemicals. Inorganic chemicals were used for such purposes (and are still in use today) until more effective organic herbicides were developed during the last 2-3 decades.



Northwest
0.5
Southwest
1.7
North Central
0.6
South Central
2.1
Northeast
0.4
Southeast
1.0
Net Imports
0.2
0.4
Government Agencies
WASHINGTON
OREGON
MONTANA
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
FLORIDA
CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VT
N.H.
CONN
N.J.
DEL

Diuron 1972 Estimated:	Millions Lbs. AI
- U.S. Production	6.5
- Imports	0.7
- Exports	0.5
- U.S. Use	6.7

Figure 35 - Materials Flow Diagram for Diuron, 1972

G. Environmental Impact Potential

Mammalian Toxicity : Diuron is in the "slightly toxic" category in regard to its toxicity to laboratory animals in acute as well as in chronic tests. Diuron may be moderately irritating to eyes, nose, throat and skin, but does not produce allergic skin reactions. The signal word "Caution" is required for labels of the 80% wettable powder formulation

Tolerances for diuron residues have been established for many crops, ranging from 0.1-7.0 ppm, 1.0 ppm for the largest number of crops.

Nontarget Organisms : Diuron is slightly toxic or relatively nontoxic to birds and wild mammals. It is moderately toxic to fishes, and appears to be quite toxic to lower aquatic organisms. No data are available on the possible build-up of diuron in food chains.

Environment : Diuron is a rather stable chemical. In the soil, it is adsorbed on clay or organic particles. Persistence of diuron in the soil depends on the rate of application and on soil properties, moisture, temperature and other environmental conditions. The higher rates of application for selective weed control may result in carryover of phytotoxic soil residues to the next season. When nonselective rates are applied, soil residues may persist for several years.

Microbial activity is the primary factor in the degradation of diuron residues in the soil. Dissipation by photodecomposition or volatilization is insignificant, except when residues are exposed to hot, dry conditions for prolonged periods. Diuron has a low leaching potential, but may be transported away from target areas with soil solids by way of erosion.

Evaluation : There are no indications of serious hazards to human health or to terrestrial ecosystems outside of target areas from the use of diuron as a herbicide. Data on effects on aquatic ecosystems, especially lower trophic levels, are inadequate for evaluation of possible hazards.

CASE STUDY NO. 16 MSMA

A. Product Description

Chemical Name: Monosodium methanearsonate

Trade Names: Ansar 170 H.C., Ansar 529 H.C., Bueno, Daconate, Phyban H.C., Silvisar 550, Weed-E-Rad

Pesticide Class: Selective herbicide

Properties: Solid, m.p. 115-119°C;* very soluble in water (100 g/100 g).

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Ansul Company	Marinette, Wisconsin	25 (est.) million lb	14 million lb
Diamond Shamrock Chemical Company	Green Bayou, Texas	20 (est.) million lb	10 million lb

C. Production Methods and Waste Control Technology

MSMA is the most widely used of the group of organoarsenic herbicides introduced in the 1950's, that also includes the octyl- and docecylammonium salts, the disodium salt (DSMA), and cacodylic acid (dimethylarsinic acid). Ansul, Diamond Shamrock, Vineland Chemical Company (Vineland, New Jersey) and W. A. Cleary Corporation (New Brunswick, New Jersey) all produce DSMA, but only Vineland and Cleary made the alkylammonium salts in 1972, and only Ansul produces cacodylic acid. Vineland and Dalton Chemicals (a subsidiary of Crystal Chemical) may have started producing MSMA since 1972. The DSMA can apparently serve as an intermediate in the manufacture of all the others (alternate routes to cacodylic acid are available).

Diamond Shamrock provided many details of its production of MSMA. The process is believed to be approximately as shown by the reaction equations below and by the production and waste schematic shown in Figure 36.

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* This melting point range is for the 1.5 hydrated form--the anhydrous MSMA decomposes and does not yield a melting point.

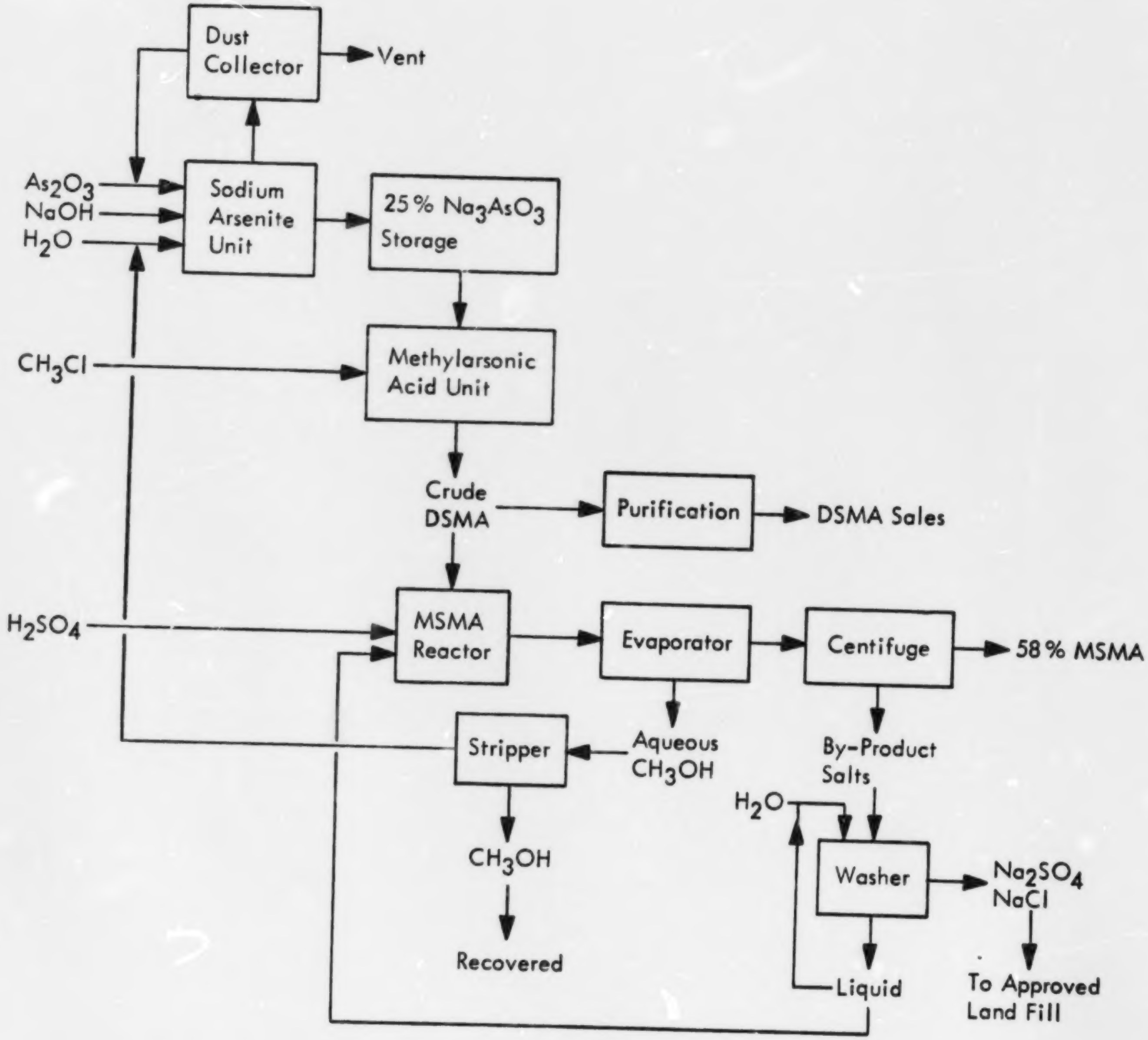

Dust Collector
Vent
As_2O_3
NaOH
H_2O
Sodium Arsenite Unit
25% Na_3AsO_3 Storage
CH_3Cl
Methylarsonic Acid Unit
Crude DSMA
Purification
DSMA Sales
H_2SO_4
MSMA Reactor
Evaporator
Centifuge
58% MSMA
Stripper
Aqueous CH_3OH
By-Product Salts
H_2O
Washer
Na_2SO_4 NaCl
CH_3OH
Recovered
Liquid
To Approved Land Fill

Figure 36 - Production and Waste Schematic for MSMA

$$As_2O_3 + 6NaOH \longrightarrow 2Na_3AsO_3 + 3H_2O$$

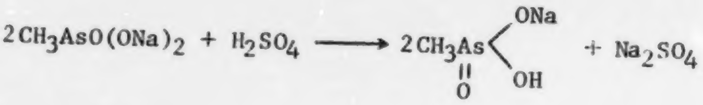
Arsenic
Trioxide

Sodium
Arsenite

$$Na_3AsO_3 + CH_3Cl \longrightarrow CH_3AsO(ONa)_2 + NaCl$$

Methyl
Chloride

DMSA



$$2CH_3AsO(ONa)_2 + H_2SO_4 \longrightarrow 2CH_3\overset{\displaystyle O}{\overset{\|}{As}}\!\left\langle\begin{array}{l}ONa\\OH\end{array}\right. + Na_2SO_4$$

DSMA

MSMA

Diamond imports arsenic trioxide (mostly from Sweden by ship and Mexico by rail, but some from France) because that manufactured in the United States (as a by-product of smelting operations) does not meet specifications. It is packed in 30-gal. metal drums. Methyl chloride is obtained by rail from Ethyl Corporation in Louisiana. Sodium hydroxide is obtained from other Diamond Shamrock facilities and is shipped in as 50% caustic by truck and by rail. Sulfuric acid is available from a number of sources.

The first step of the process is performed in a separate, dedicated building. The drums of arsenic trioxide are opened in an air-evacuated chamber and automatically dumped into the 50% caustic. A dust collection system is employed. The drums are washed carefully with water, the wash water is added to the reaction mixture, and the drums are crushed and are sold as scrap steel. The intermediate sodium arsenite is obtained as a 25% solution and is stored in large tanks prior to further reaction. In the next step, the 25% solution of sodium arsenite is treated with methyl chloride to give the disodium salt, DSMA. Diamond sells some DSMA, for herbicide uses, but DSMA must be used at higher application rates and is not as soluble as MSMA, and has therefore never become as popular as MSMA.

In order to obtain MSMA, the solution is partially acidified with sulfuric acid and the resulting solution is concentrated by evaporation. The active ingredient is sold at a number of concentrations, but ~ 58% is the maximum concentration that can be prepared without encountering an undesirable increase in viscosity.

As the aqueous solution is being concentrated, a mixture of sodium sulfate and sodium chloride precipitates out; about 0.5 lb per 100 lb of active ingredient. These salts, a troublesome disposal problem because they are contaminated with arsenic, are removed by centrifugation, washed in a 5-stage counter current washing cycle, and then disposed of in a dump which is registered with the State of Texas. This dump is situated on nearly impermeable Beaumont clay, and has no aqueous runoff. Disposal of arsenic-contaminated salts appears to be a major problem for Ansul, which apparently does not have separation and washing facilities equivalent to Diamond's.

Diamond Shamrock's plant is a "low effluent" plant, although they do discharge aqueous waste. Methanol, a side product of methyl chloride hydrolysis, is recovered and used elsewhere in the plant, and recovered water is recycled. Two equalization ponds are used and the discharge of arsenic averages about 0.7-0.8 ppm, well under the 1 ppm allowed by their permit from the Texas Water Quality Board. (This level is lower than the arsenic level in many household detergents.) The total amount of arsenic discharged amounts to only about 1/2 lb per day.

D. Formulation, Packaging, and Distribution

The MSMA is formulated by Diamond Shamrock as liquids of 4-lb technical ingredient per gallon and 6-lb AI per gal. Most of their MSMA is shipped in tank cars or tank trucks, but some is shipped in 30- and 55-gal. drums that are lined with a baked phenolic resin. Diamond Shamrock also packages the MSMA in 1- and 5-gal. polyethylene jugs. The MSMA is sold both with and without a surfactant. Most of Diamond's MSMA is used on cotton in the Delta Region, although some is sent to California. Some MSMA (10-15% of production) is exported to the Arabian countries, Israel, and South and Central American countries.

Ansul Company sells MSMA plus a surfactant in two concentrations: 36% (4 lb AI/gal) and 48% (6 lb AI/gal). Both forms are packaged in 1-gal. plastic jugs, 5-gal. liquid steel pails, and 30-gal. lined drums. In addition, Ansul formulates two MSMA products, 51% (6.67 lb AI/gal) and 58% (8 lb AI/gal), that do not contain surfactant in the formulation.

E. Use Patterns

General : MSMA, along with DSMA (disodium methanearsonate) and cacodylic acid, belong to the organic pentavalent arsenicals which are distinctly less toxic to mammals than organic derivatives of trivalent As, or inorganic sodium arsenite or arsenic trioxide. The selective, post-emergent efficacy against hard-to-kill grass weeds is a unique property of MSMA. It has been in commercial use for about 10 years. Its volume of use today exceeds that of all other organic As herbicides by a wide margin. Its use leveled off several years ago, but has shown a renewed upward trend recently. Agricultural uses amount for most of the estimated domestic consumption of MSMA.

Action :	Selective, postemergence contact herbicides. Must contact green plant tissues to be effective. Exact mode of action not known.
Target Crops :	Cotton; established lawns and turf (except St. Augustine or centipede grasses); noncropland; interspaces between tree or plant bases in nonbearing fruit plantings.
Target Weeds :	Johnsongrass and other grass weeds, some broadleaf weeds. Mixed with 2,4-D/2,4,5-T brush killers, MSMA increases kill or dieback of woody weeds.
Application :	Cotton: preplant broadcast (only if planting is delayed and weeds have emerged), or as a directed postemergence spray on emerged weeds. Must be used with sufficient surfactant. Used by itself or in combination with certain other herbicides, by ground equipment. Established lawns and turf: broadcast or spot application by ground equipment. Noncropland: sprayed on foliage of vegetation to be controlled, by ground equipment. Good coverage essential.

	Cotton	Lawn/Turf	Noncropland
Rates of Application, Lb AI/Acre :	2.0	2.7-6.0	3.0-6.0
Frequency of Application :	1-2 per season	Multiple	Multiple
Time of Application :	3 in. to first bloom (late spring, early summer)	Variable	Variable

Estimated Distribution : (All figures in millions of lb AI/year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
24	Negligible	5	19

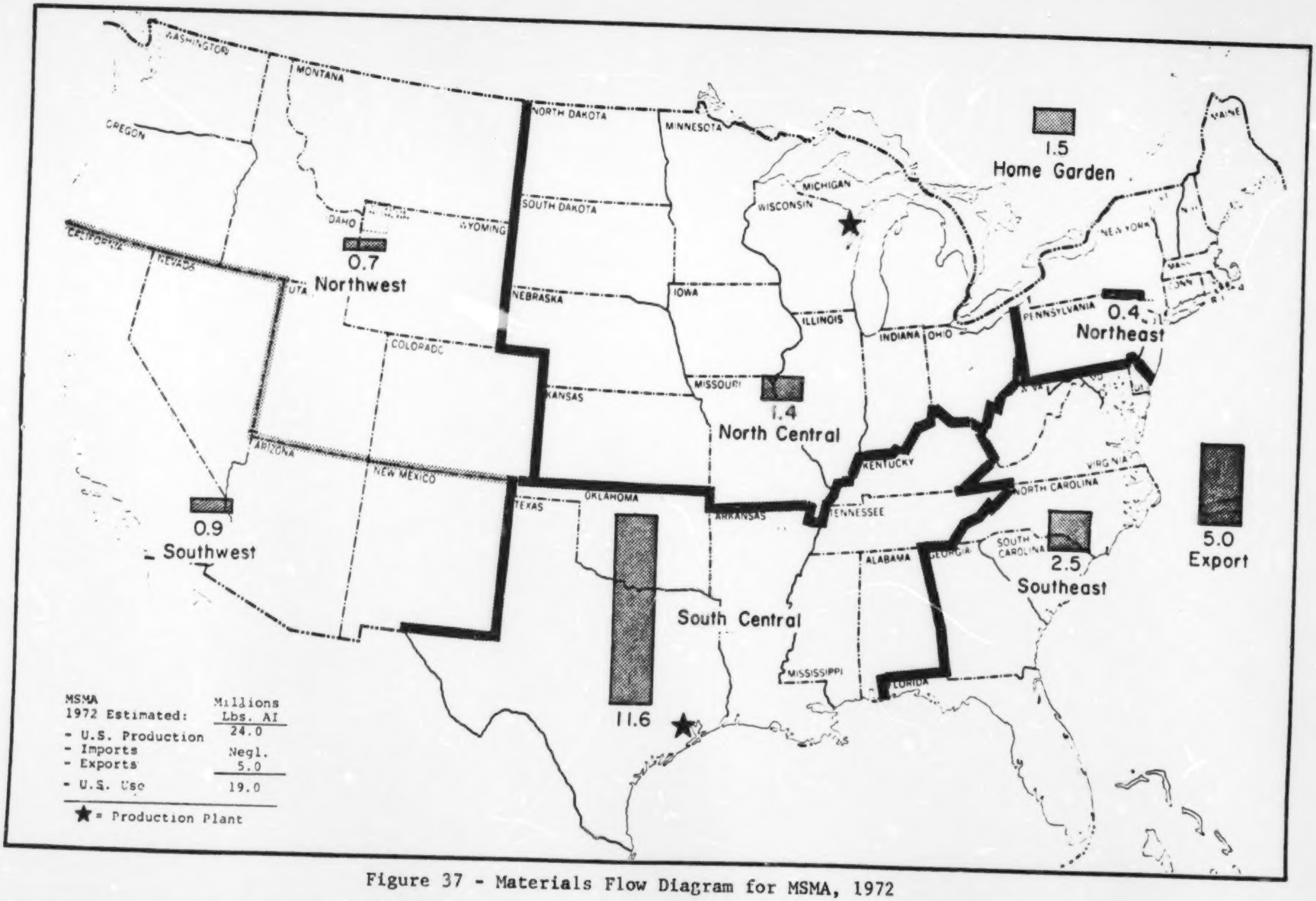

WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
NEW YORK
MASS
CONN
R I
MAINE
0.7
Northwest
0.9
Southwest
1.4
North Central
11.6
South Central
1.5
Home Garden
0.4
Northeast
2.5
Southeast
5.0
Export
MSMA
1972 Estimated: Millions Lbs. AI
- U.S. Production 24.0
- Imports Negl.
- Exports 5.0
- U.S. Use 19.0
★ = Production Plant

Figure 37 - Materials Flow Diagram for MSMA, 1972

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Sub-totals	Home and Garden[a]	Totals
NE	--	0.3	0.1	0.4		
SE	1.5	0.8	0.2	2.5		
NC	0.5	0.7	0.2	1.4		
SC	10.0	1.4	0.2	11.6		
NW	0.2	0.4	0.1	0.7		
SW	0.3	0.4	0.2	0.9		
Totals	12.5	4.0	1.0	17.5	1.5	19.0

---

[a] Distribution not known.

A materials flow diagram for MSMA is shown in Figure 37.

F. Alternatives

Chemicals : On cotton: Fluometuron (Cotoran); prometryne (Caparol); diuron (Karmex); norea (Herban). None of these are as effective and as inexpensive as MSMA in providing post-emergence control of hard-to-kill grass weeds. On established lawns and turf: other arsenical herbicides. On noncropland: many herbicides are used, but none would be direct replacements for the organic arsenicals in physical, chemical and biological properties.

Nonchemicals : Cotton weeds can be removed mechanically by cultivation and/or hand labor. Grass weeds including crabgrass, nutsedge and others can be removed from lawns and turf by hand. Where weed infestation pressure is heavy, this would be prohibitively expensive and ineffective compared to the use of herbicides. Nonchemical controls thus would be feasible only in situations of low weed density.

G. Environmental Impact Potential

Mammalian Toxicity : The acute oral LD-50 of pure MSMA to rats is about 900 mg/kg, placing it into the "slightly toxic" category by this parameter. Tests with rabbits show that MSMA is essentially nonirritating to nose, eyes, and skin. Labels of MSMA formulations carry the signal word "Caution." No data are available on the chronic toxicity (2-year feeding tests) of MSMA; however, 90-day feeding tests show no effect with the amounts: dogs - 30 ppm MSMA per day; rats - 100 ppm MSMA per day. Tolerances for residues of MSMA have been established (all expressed as As_2O_3) for citrus fruits at 0.35 ppm, cottonseed at 0.7 ppm, and cottonseed hulls at 0.9 ppm.

Arsenicals as a group have been suspected of producing cancer. Scientists around the world have debated the evidence presented for or against carcinogenicity of arsenicals for many years. The question of carcinogenicity is still unproven although attempts to produce carcinoma in laboratory tests have failed.74/

Nontarget Organisms : MSMA appears to be relatively nontoxic to fishes and soil organisms, and because of its use patterns, pose a minimal hazard to wild mammals. In 8-day feeding tests, MSMA was also shown to be relatively nontoxic to birds. A study on lower aquatic organisms and food chain buildup is currently in progress.

Environment : Degradation studies on MSMA showed that after application to soil, phytotoxicity decreases. While the metabolism of most organic herbicides leads to the formation of less toxic products, metabolism of the methanearsonic acids in soils yield the inorganic arsenate, a form that is more toxic to mammals but that occurs in nature. According to a spokesman for one of the producers, degradation may proceed by two routes; C-As cleavage to CO_2 and arsenate (aerobic conditions) or reduction to volatile methylarsines (anaerobic or oxidative conditions). The latter process, the most common in nature, yields a salt of orthoarsinic acid. This acid is naturally occurring and strongly bound to metals in soils and sediments, which greatly deactivates it.

Evaluation : There is no evidence of serious hazards to human health from the use of MSMA as a herbicide in accordance with label directions. The question of possible carcinogenicity of organic arsenicals in general is unresolved.

Data on possible effects of MSMA and its residues on terrestrial and aquatic ecosystems show it to be of minimal hazard if used as directed. Data on effects on lower aquatic organisms are insufficient at this point to allow an evaluation of possible hazards.

In the National Soils Monitoring Program, elemental arsenic residues were found at 99.3% of the sites sampled, ranging from 0.25-107.45 ppm, averaging 6.43 ppm. The authors believe that most of this arsenic was from natural sources, although they did not rule out contributions from agricultural sources. Among the 12 states that had the highest arsenic residue levels in the soil, only one, i.e., Arkansas, is a cotton growing state. Thus, there were no correlations between high soil residue levels of arsenic and the growing of cotton, the crop that receives the lion's share of arsenical herbicide applications.

CASE STUDY NO. 17 SODIUM CHLORATE

A. Product Description

Chemical Name: Sodium Chlorate

Trade Names: Altacide, Atratol, Chlorax, De-Fol-Ate, Drop-Leaf, Fall, MBC, Monobor-chlorate, Polybor Chlorate, Rasikal, Shed-A-Leaf, Tumbleaf

Pesticide Class: Semipermanent sterilant, herbicide, defoliant, dessicant

Properties: Water-Soluble, White crystals, m.p. 248°C, b.p., decomposes

B. Manufacturers

Name	Plant Location	Plant Capacity (MM lb/yr)	Estimated 1972 Production a/
Brunswick Chemical	Brunswick, Georgia	14	0
Georgia-Pacific	Bellingham, Washington	7	0
Hooker Industry Chem.	Columbus, Mississippi	125	1.3
	Niagara Falls, New York	31	0.3
	Taft, Louisiana	40b/	0.4
Huron Chemicals	Butler, Alabama	8	0
	Riegelwood, North Carolina	14	0
Kerr-McGee	Henderson, Nevada	60	26.6
	Aberdeen, Mississippi	65	2.6
Penn-Olin	Calvert City, Kentucky	62	2.5
Pennwalt	Portland, Oregon	33	1.3
		459	35.0a/

---

a/ Portion of production that is used for herbicidal purposes.
b/ Planned capacity is expected to reach 90 MM lb/yr by January 1975.

C. Production Methods and Waste Control Technology

Sodium chlorate is produced by the electrolysis of an acidified sodium chloride solution, as illustrated by the equation below:

$$NaCl + 3H_2O \xrightarrow[\text{6 Faradays}]{\text{Electrolysis}} NaClO_3 + 3H_2$$

A production and waste schematic is shown in Figure 38. The process has been described in considerable detail.75/ Salt (sodium chloride) is charged into a dissolving tank, where it is converted into a saturated solution by the addition of soft water. The condensate from the evaporator serves as a convenient source for the latter. Generally some mud and salt impurities collect at the bottom of the dissolver, from which they are periodically discharged. If the salt contains a high percentage of calcium and magnesium salts, it is usually necessary to purify the solution by precipitation, settling, and filtration of the foreign salts.

The clarified saturated salt solution is run into a feed tank, where it is mixed with dilute hydrochloric acid. A concentration of about 0.5% acid is usually maintained so that the average pH of the brine solution in the cells will be approximately 6.5. Sodium dichromate (about 0.2%) is added to inhibit cell corrosion caused by the liberated hypochlorous acid (from the hydrochloric acid present).

The saturated acidulated brine is fed into banks of electrolytic cells, operating batchwise or continuously, maintained at 4[illegible] to 45°C by cooling water. The construction and operation of the cells vary in different installations. Generally the cell bodies are constructed of steel (some are cement-lined) and make use of steel cathodes and graphite anodes.* There is no diaphragm in the cell, and the electrodes are closely spaced to allow mixing of the products. The electrolysis actually yields chlorine at the anode and sodium hydroxide at the cathode. However, because of the foregoing conditions, good mixing occurs, resulting in the formation of sodium hypochlorite (NaClO) and then sodium chlorate ($NaClO_3$). Hydrogen is liberated during the electrolysis and may be either vented or recovered by suitable means. One producer noted that it is considering the recovery of hydrogen for use as fuel because of the energy crisis.

The cells require DC electric power; it is obtained by converting AC power in mercury-arc or motor-generator rectifiers.

The cell liquors, after electrolysis, are discharged into a settler. In batch operation, generally 75% of the salt is converted. The liquor in the settler may be heated to 90°C to destroy any residual hypochlorite.

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* As discussed later in this section, chlorate producers are in the process of switching over from graphite to dimensionally-stable anodes.

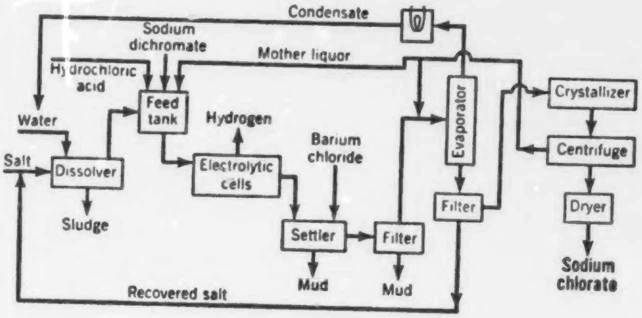
Condensate
Sodium dichromate
Mother liquor
Hydrochloric acid
Feed tank
Hydrogen
Water
Barium chloride
Salt
Dissolver
Electrolytic cells
Evaporator
Crystallizer
Centrifuge
Filter
Dryer
Sludge
Settler
Filter
Mud
Mud
Sodium chlorate
Recovered salt

Figure 38 - Production and Waste Schematic for Sodium Chlorate[75]/

The chromate ions remain in the liquor and protect steel equipment from corrosion further along in the process. Formates or urea may be added to the liquors in the settler to convert the residual hypochlorite to chlorate. Graphite mud from the anodes settles to the bottom of the tank and is periodically removed.

The liquor contains about 50% sodium chlorate. It is decanted from the top of the settler, passed through a sand filter (if necessary), and charged into double-effect evaporators. Here it is concentrated to approximately 70 to 75% sodium chlorate and is filtered while hot. The unconverted sodium chloride is less soluble than the chlorate at boiling temperatures and is thrown out of solution. The recovered salt (filter cake) is returned to the dissolver for reuse.

The filtrate is passed into a crystallizer, where it is cooled (below 30°C) to precipitate sodium chlorate crystals. The product is centrifuged, washed, and dried in rotary dryers. The centrifuge mother liquor and first wash liquors are generally returned to the evaporator for subsequent concentration, although periodically they are returned to the cell feed tank for reprocessing.

The dried product is ground to proper mesh size and screened to yield sodium chlorate crystals, which assay about 99.5%. Although the initial conversion of sodium chloride to chlorate ranges from 50 to 75%, the overall yield (based on the salt charged) is about 95%. The current efficiency averages 75 to 85%, depending on the individual plant.

Sodium chlorate may be recovered from the cell liquors by other methods than the previously described concentration process. These other procedures include direct crystallization by refrigerative cooling (about 0°C) and salt exchange (isothermal crystallization) where the chlorate is salted out by addition of sodium chloride.

The chief variations in electrolytic processes for sodium chlorate are in recovery of the product from the cell liquors, which may be accomplished by chilling, salting out, or evaporation. The particular method used depends on conditions existing at a given plant. Considerable care must be taken in the operation of any chlorate plant, because of the potential fire and explosion hazard. A technical operating staff well versed in the control of operating hazards is accordingly a necessity in the industry.

Waste control technology: Waste control techniques vary considerably as indicated in the following description of methods provided by Hooker Chemical Company and Pennwalt.

At the Hooker Chemical Company plant, Columbus, Mississippi, carbon from the electrodes is lost at a rate of 15 lb/ton of $NaClO_3$ produced. Approximately 12 lb of carbon is recovered to be sold. Most of the remaining 3 lb ends up in the "mud" waste stream of the process.

Some of the carbon is oxidized to CO_2 in the cell and is given off with the hydrogen gas formed in the cell. The recovered carbon comes from the filtration system. Recovered carbon, including used electrodes, is sold. Plant emissions consist primarily of the "mud" and gaseous effluents. The mud consists of the bottoms of the cells and the settling and filtration systems following the addition of $BaCl_2$ to the cells' liquor. The most important mud constituents are barium chromate, barium sulfate, and graphite from the electrodes. This mud is discharged into the river nearby. Hooker plans to start landfilling the "mud" in 1974 or 1975.

Gaseous emissions come from the cells in the form of hydrogen, CO_2 (less than 1% of hydrogen), and traces of chlorine. They are vented directly to the atmosphere. Hooker is not aware of any chlorinated hydrocarbons being formed in the cells.*

The process has no liquid effluent except for occasional leaks. A water scrubber is used to remove the $NaClO_3$ from the gases emitted from the dryers'; however, the water in the scrubber is then recycled into the evaporator system to recover the $NaClO_3$.

At the Pennwalt plant barium chloride is not used to recover chromate but sells the finished cell liquid, which contains chromate, chlorate and chloride, to paper manufacturers (who utilize the chlorate). Apparently, all of this liquid is sold, because there is no liquid effluent from this plant.

A small amount of chromate-containing water is formed, however, in another manner; in the evaporation of the cell liquid (which contains chlorate, chloride and chromate) a vacuum is applied, and some of this liquid is entrained into the vapor phase. This entrained liquid is subsequently absorbed in the condensate of the steam jet, which is used to generate the vacuum. There is some current concern about the proper disposal of this chromate-containing water, even though the total volume is small.

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* The possibility of by-product chlorinated hydrocarbons is discussed later in this section.

Chromate is also used as a corrosion inhibitor in the cooling water. Other corrosion inhibitors had been considered, particularly certain organic nitrogen compounds, but these have been rejected because of the potential hazard: the hot chlorate solution could explosively oxidize the organic nitrogen compounds. The proper disposal of this chromate-containing water is also of concern.

Pennwalt apparently does not have the same kind of mud disposal problem as other chlorate producers. The brine is treated for chlorine as well as chlorate; therefore, the mud is a chlorine (not a chlorate) problem. They also treat the brine prior to electrolysis with sodium carbonate in order to precipitate most of the magnesium and calcium. This precipitated material, also called "mud" is presently allowed to accumulate at the Pennwalt chlorate plant. Evidently, they have plenty of space and this disposal technique is acceptable.

Possibility of the Formation of By-Product Chlorinated Hydrocarbons: In the manufacture of chlorine, small quantities of chlorinated hydrocarbons are formed, including some that are highly toxic and difficult degraded in the environment (e.g., hexachlorobenzene). These compounds are evidently formed as a result of interaction of chlorine with the graphite electrode. These materials are practically eliminated from chlorine, because of a distillation step. However, in sodium chlorate manufacture, no comparable step occurs. Furthermore, in sodium chlorate manufacture, the brine is recirculated and this procedure could allow the gradual build-up of chlorinated hydrocarbon by-products in the brine.

Some industry sources confirm that by-product chlorinated hydrocarbons are actually produced during sodium chlorate manufacture. However, no analytical evidence is available and detection of hexachlorobenzene has not been reported.

Dimensionally Stable Electrodes: According to Pennwalt, all chlorate producers are presently in the process of switching from graphite to the more efficient metallized electrodes, i.e. the so-called dimensionally stable anodes (DSA). The use of the new electrodes eliminates the formation of wastes resulting from the deterioration of the graphite anode. These would include the graphite "muds" and any chlorinated hydrocarbons formed during the electrolysis.

D. Formulation, Packaging, and Distribution

Most of the sodium chlorate that is manufactured is used in paper mills and is either generated on site or is shipped in tank car quantities. Sodium Chlorate is sold for agricultural purposes by the following companies: Kerr-McGee Corp., Hooker Chemical Corp., Penn-Olin Chemical Co., Pennwalt Corp. and U.S. Borax Co. Solid sodium chlorate is often formulated with borates to reduce the fire hazard, but aqueous solutions are safe and do not require borates. Approximately 1% of Hooker's chlorate total production goes to agricultural use. These shipments are made in steel drums of 50, 100, 450, and 600 lbs. net or in bulk in tank cars. The agricultural shipments are sent to Oxychem, U.S. Borax and Chemical Corp., and Rhodia Inc., Chipman Division. None of Hooker's distribution is west of Texas with most of the product going to Kansas, Kentucky, Texas, Oklahoma, Arkansas, Louisiana, and Missouri.

The U.S. Borax plant in Columbus, Mississippi receives its chlorate from and formulates a 30% sodium chlorate-70% metaborate mixture called Monobor. The formulation is in dedicated equipment and distribution is nationwide. The U.S. Borax plant in California receives its sodium chlorate primarily from Kerr-McGee Corp. (Henderson, Nevada) and produces essentially the same products as the other U.S. Borax plant. The Monobor products are packaged in 50 lb. multi-wall bags.

Pennwalt estimates 4% of their production goes to agriculture. The percentage is about the same for Penn-Olin (jointly owned by Olin Corp. and Pennwalt Corp.). Their solid product is shipped in drums and in bulk. Some of their pure sodium chlorate is also sold to U.S. Borax.

E. Use Patterns

General : Sodium chlorate is one of the most heavily used inorganic herbicides. At high rates of application, it kills all vegetation nonselectively. At lower rates, it is effective as a defoliant/desiccant. This latter use has declined, but may become much more widely practiced as fuel shortages increase the desirability of field-drying many crops. Sodium chlorate is a strong oxidizing agent and, used by itself, without fire retardants, it becomes a serious fire and explosive hazard if in contact with organic matter.

Action : Nonselective herbicide, destroys germinating seeds, plant roots and foliage, and inhibits plant growth. Defoliant and desiccant action at lower rates.

Target Crops : Kills all vegetation, including deep-rooted perennial weeds, at high rates of application. More effective on broadleaf plants than on grasses.

	Vegetation Control	Defoliation/desiccation
Rates of Application	300 - 1,000 lbs. AI/acre (Up to 1,300 lbs. AI/acre)	4-6 lbs. AI/acre (Up to 16 lbs. AI/acre on potatoes)
Frequency	As needed, usually less than 1 application per year	One treatment/season
Time of Application	Variable	Fall (just prior to crop harvest)

U.S. Production	Imports	Exports	Domestic Consumption
400	30.0	Negl.	430 Total 35 Pesticide Use

Pesticidal Use by Category and Geographic Region

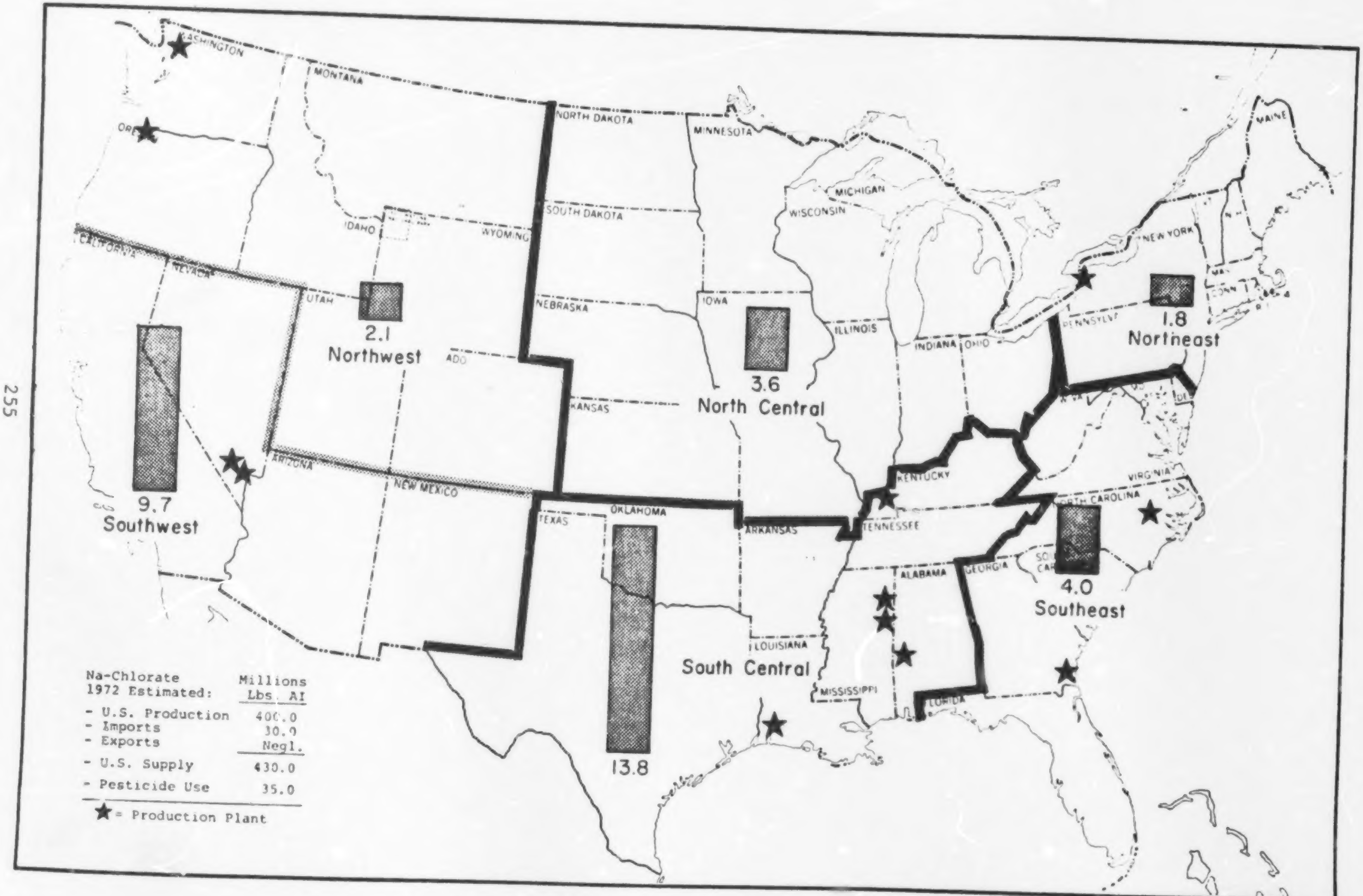
Region	Agric.	Industr. Comm.	Gov't Agn.	Home & Garden	Totals
NE	--	1.7	0.1		1.8
SE	--	3.8	0.2		4.0
NC	--	3.4	0.2		3.6
SC	7.5	6.1	0.2		13.8
NW	0.1	1.9	0.1		2.1
SW	7.4	2.1	0.2		9.7
Totals	15.0	19.0	1.0	Negl.	35.0

A materials flow diagram for Sodium Chlorate is shown in Figure 39.

F. Alternatives

Chemicals : Many other herbicides and herbicide combinations are used for vegetation control. None of these are similar to sodium chlorate in chemical, physical and biological properties.

Nonchemical : Nonselective removal of unwanted vegetation from industrial and commercial premises and right-of-ways is not feasible without the use of chemicals. Inorganic chemicals including sodium chlorate have been used for such purposes since before 1900.


2.1
Northwest
3.6
North Central
1.8
Northeast
4.0
Southeast
13.8
South Central
9.7
Southwest
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
NORTH CAROLINA
VIRGINIA
NEW YORK
PENNSYLVANIA
CONN
MAINE
★ = Production Plant

Na-Chlorate 1972 Estimated:	Millions Lbs. AI
- U.S. Production	400.0
- Imports	30.0
- Exports	Negl.
- U.S. Supply	430.0
- Pesticide Use	35.0

Figure 39 - Materials Flow Diagram for Sodium Chlorate, 1972

G. Environmental Impact Potential

Mammalian Toxicity : The oral acute LD-50 of sodium chlorate to rats is is 5000 mg/kg, placing it into the slightly toxic to relatively nontoxic category by this criterion. Sodium chlorate is severely irritating to mucuous membranes. No data are available on its acute inhalation toxicity, nor on its chronic toxicity, and no residue tolerances have been set. Cottonseed has been exempted from the requirement of a tolerance, and an additional exemption has recently been requested for residues on sorghum that may result from the use of sodium chlorate as a desiccant in grain sorghum productions. Labels require the signal word "Caution."

Nontarget Organisms : Sodium chlorate is toxic to livestock, birds and other animals feeding in treated areas. It is moderately toxic to fish, and probably highly toxic to soil organisms and other forms of life in target areas.

Environment : At the high rates of application required for complete vegetation control, sodium chlorate is quite persistent in the soil. It is highly water soluble and thus subject to leaching, or removal from treated areas by surface run-off. No data are available on the routes, rates or mechanisms of its degradation in the environment. Phytotoxic effects in the soil persist for one year or longer following application at commercial use rates.

Evaluation : Sodium chlorate may be severely irritating to operators. It is a strong oxidizing agent and, while not flammable by itself, renders dangerously flammable organic matter with which it comes in contact, including clothes, shoes, dead vegetation, etc. Addition of fire retardants (see above under "Application") is designed to prevent this hazard. No subacute or chronic hazards to human health have been attributed to the use of sodium chlorate as a herbicide.

Data on its possible transport away from target areas, environmental mobility, and pathways are not sufficient for an evaluation of hazards in this regard. All weed control uses combined account for less than 10% of the total U.S. consumption of sodium chlorate.

CASE STUDY NO. 18 TRIFLURALIN

A. Product Description

Chemical Name: α,α,α-Trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine

Trade Names: Treflan, Triflurex

Pesticide Class: Selective herbicide; Nitroaromatic

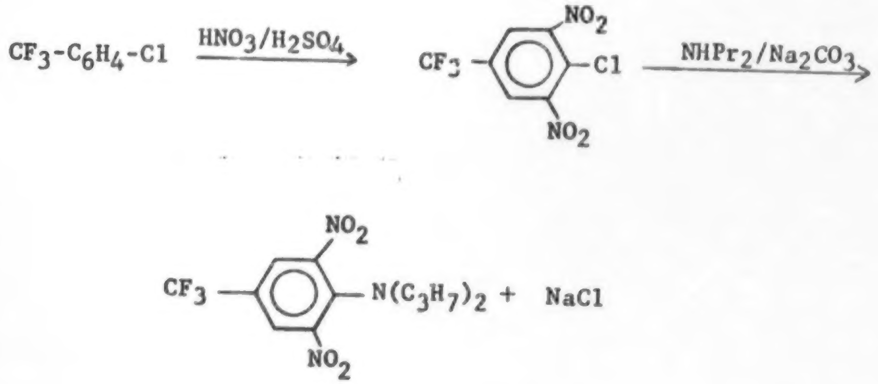
Properties: Low melting solid of low volatility and water solubility; very low toxicity; nonpersistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Eli Lilly and Company	Lafayette, Indiana	35 (estimate) million lb	21 million lb

C. Production Methods and Waste Control Technology

Information on production methods and waste control technology for trifluralin have been reported.[1] The reaction chemistry is:



A production and waste schematic is shown in Figure 40.

Process water and NaCl go to waste disposal; NO_x to scrubbers; H_2SO_4 is upgraded and sold; no solid wastes from Treflan® (trifluralin). The waste disposal plant uses neutralization, settling, aeration and biological. The effluent discharged is cleaner than the river water and contains no Treflan®. All liquid formulation and filling equipment is dedicated. There are few problems with leaks. Corrugated layers between cans and strapped pallets are used for shipment.

D. Formulation, Packaging, and Distribution

Eli Lilly produces trifluralin on site by a continuous process. It is formulated as Treflan® 4-lb/gal. (44.5% AI) packaged in 5-gal. lined cans and in metal quarts, and as 2.5% and 5% granular formulations. Usage breakdowns are as follows: ~ 60% on soybeans, ~ 30% on cotton, and ~ 10% on other usages. Ten percent of the technical trifluralin is exported.

E. Use Patterns

General : Trifluralin was the first dinitroaniline-type herbicide to be developed. It remains the leading herbicide in this group to date, even though a number of competitive compounds have since been developed and are currently in various stages of commercial or experimental use. Dinitroaniline-type herbicides as a group are expected to further increase in volume of use. The uses of trifluralin for nonagricultural purposes are negligible or nil.

Action : Selective, soil-applied, preplant or preemergence herbicide for control of annual grass weeds and some annual broadleaves. Affects seed germination and other growth processes. Inactive if applied to plant foliage.

Target Crops : Soybeans, cotton, Spanish peanuts, beans, sugar beets, sugarcane, and many other field and vegetable crops. Registered for use on more than 50 crops.

Target Weeds : Annual grass weeds, including Johnsongrass seedlings (rhizomes at higher rates), wild cane, pigweed, and lambsquarter. Ineffective against most other broadleaf weeds, and against yellow nutsedge.

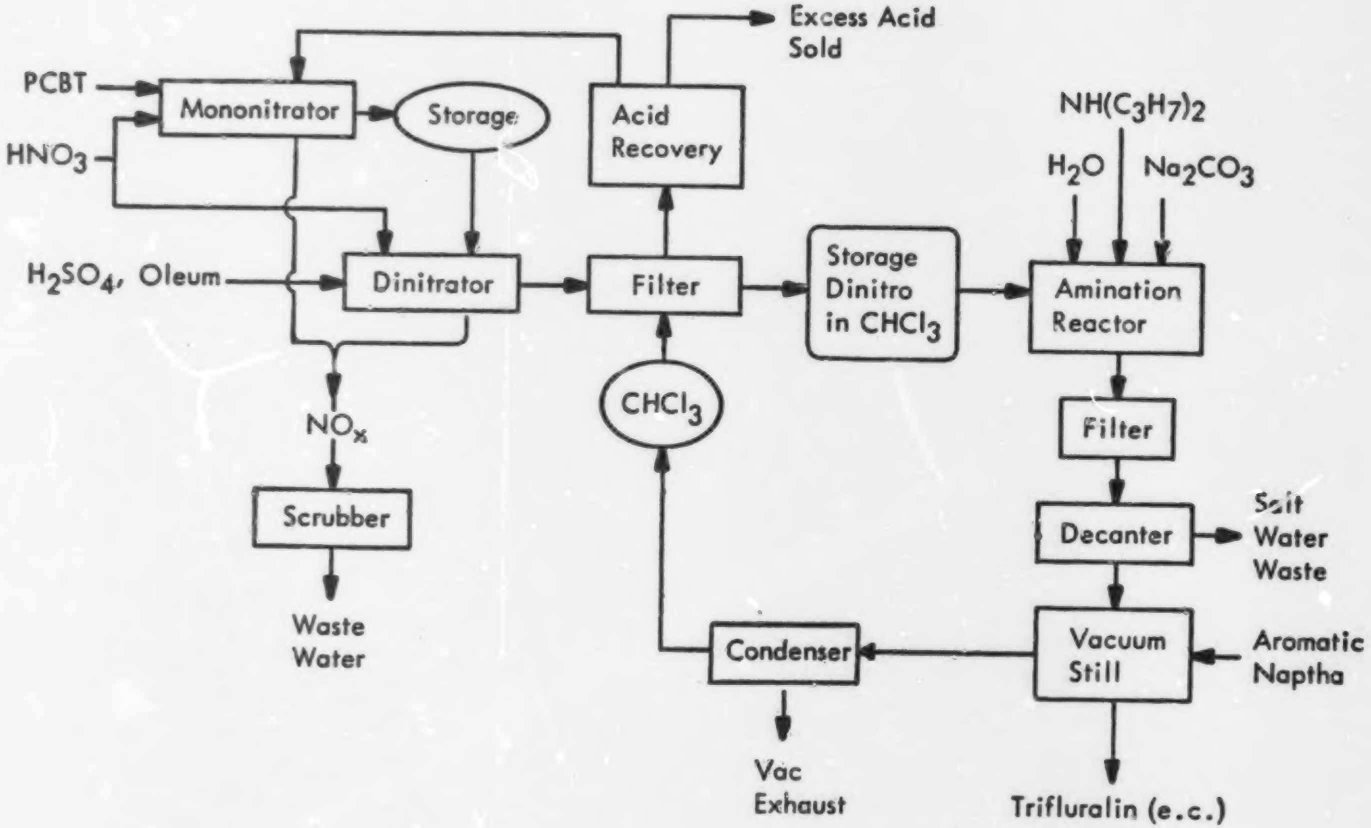

PCBT
HNO3
H2SO4, Oleum
Mononitrator
Storage
Dinitrator
NOx
Scrubber
Waste Water
Acid Recovery
Excess Acid Sold
Filter
CHCl3
Storage Dinitro in CHCl3
Condenser
Vac Exhaust
NH(C3H7)2
H2O
Na2CO3
Amination Reactor
Filter
Decanter
Salt Water Waste
Vacuum Still
Aromatic Naptha
Trifluralin (e.c.)

Figure 40 - **Production and Waste Schematic for Trifluralin**[1/]

Application : Preplant, preemergence; must be soil-incorporated promptly. Used mostly by itself, sometimes followed by another herbicide against uncontrolled broadleaf weeds. Most material applied broadcast by ground equipment.

Rates of Application : 0.5-1.0-lb AI/acre. Up to 2.0-lb AI/acre for fall applications, for use on sugarcane, and in pecan and citrus plantings.

Frequency : Once per season.

Time of Application : Mostly spring, prior to planting of crop. Small percentage of applications preceding fall.

Estimated Distribution : (All figures in millions of lb AI/year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
21	Nil	4	17

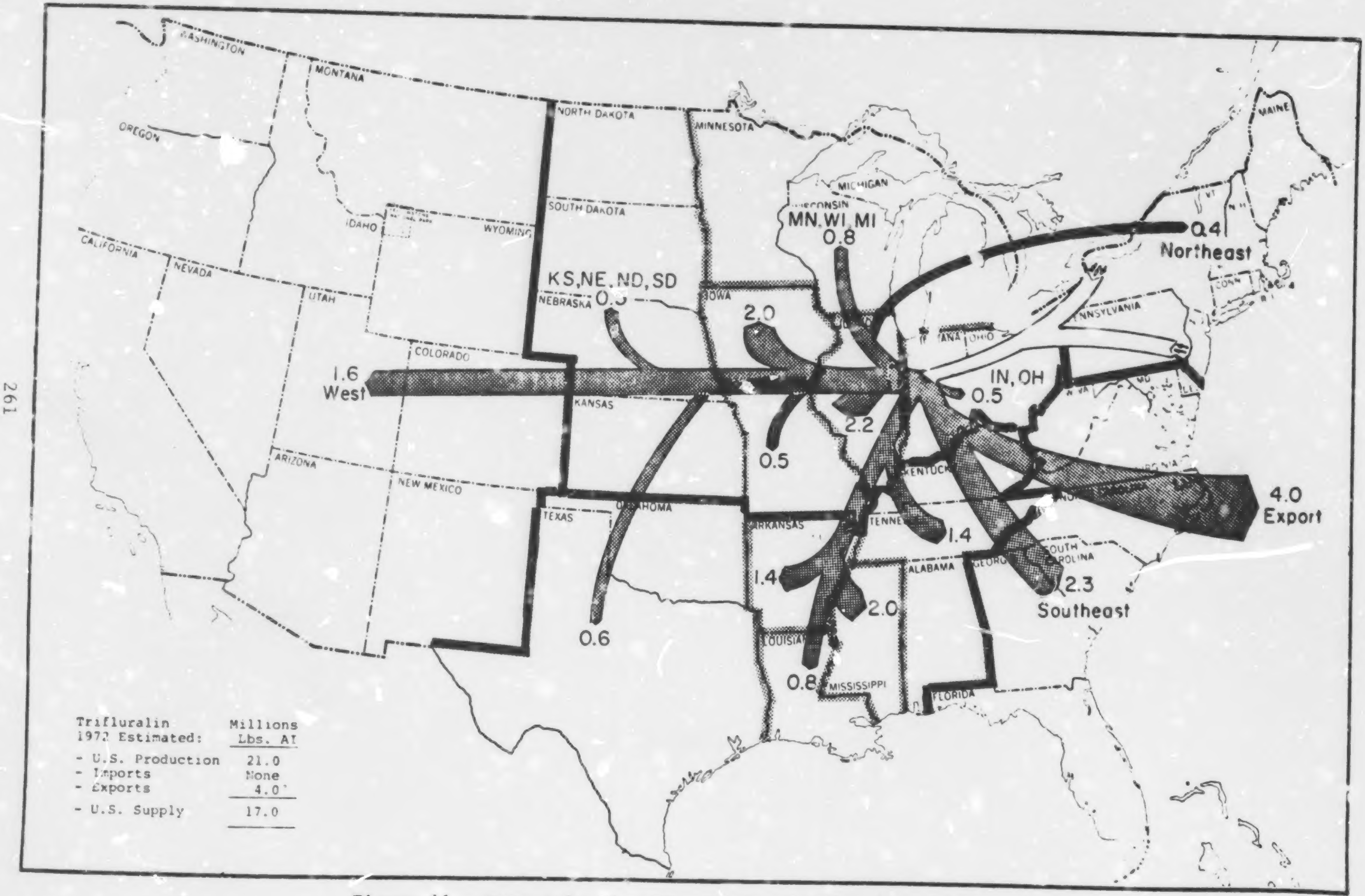
DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	0.4	Small	Negligible	Small	0.4
SE	2.3				2.3
NC	6.4				6.5
SC	6.1				6.2
W	1.6				1.6
Totals	16.8	0.2[a]			17.0

---

[a] Too small to break out, apportioned and included in total distribution.

A materials flow diagram for trifluralin is shown in Figure 41.



4.0
Export
0.4
Northeast
2.3
Southeast
MN,WI,MI
0.8
KS,NE,ND,SD
0.5
2.0
1.6
West
IN,OH
0.5
2.2
0.5
1.4
1.4
2.0
0.8
0.6
WASHINGTON
OREGON
CALIFORNIA
MONTANA
IDAHO
NEVADA
UTAH
WYOMING
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
WISCONSIN
MICHIGAN
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
TENNESSEE
KENTUCKY
INDIANA
OHIO
PENNSYLVANIA
GEORGIA
SOUTH CAROLINA
FLORIDA
MAINE
VT
N H
CONN
MD

Trifluralin 1972 Estimated:	Millions Lbs. AI
- U.S. Production	21.0
- Imports	None
- Exports	4.0
- U.S. Supply	17.0

Figure 41 - Materials Flow Diagram for Trifluralin, 1972

F. Alternatives

Chemicals : Other dinitroaniline-type herbicides including nitralin (Planavin), dinitramine (Cobex) and others; chloramben (Amiben), alachlor (Lasso), linuron (Lorox), vernolate (Vernam), fluorodifen (Preforman, Soyex), chlorobromuron (Maloran, Bromex), diphenamid (Enide), and others.

Nonchemicals : Mechanical removal of weeds by cultivation, hoeing, hand-pulling, changing crop rotation, planting dates, etc. None of these measures work too well on grass weeds, and all of them would be more expensive than effective herbicides, except in rather clean fields.

G. Environmental Impact Potential

Mammalian Toxicity : The mammalian toxicity of trifluralin is low. The chemical is relatively nontoxic to laboratory animals by the oral, dermal and inhalation routes. The solvent system used in the 4-lb/gal. EC, the most common commercial formulation, is more toxic than the active ingredient. Therefore, while the active ingredient is classified as "relatively nontoxic" the 4-lb/gal. EC falls within the "slightly toxic" category and requires the signa [illegible] tion" on the label.

Trifluralin AI is not irritating to mucuous membranes and has no known cumulative toxic effects. Its chronic toxicity is low.

Residue tolerances have been established for many crops, ranging from 0.05-2.0 ppm.

Nontarget Organisms : Trifluralin is highly toxic to fish, toxic to lower aquatic organisms, and relatively nontoxic to birds and wild mammals. Its toxicity to soil organisms is not known. No published data are available regarding its possible bioaccumulation or build-up in food chains

Environment : Trifluralin is rapidly inactivated unless it is incorporated into the soil promptly after application. In the soil, it is strongly adsorbed on organic matter and clay colloids. It is degraded by microbial action as well as by nonbiological factors. Trifluralin is moderately persistent in the soil, 80-90% of an applied rate will normally degrade during the growing season. Trifluralin does not readily leach through the soil, but may be transported away from treated areas adsorbed on solids via soil erosion.

Evaluation : No serious hazards to human health have been attributed to this date to the use of trifluralin for weed control as directed on the label. Trifluralin presents a serious hazard to fish if water becomes contaminated. Transport of trifluralin soil residues from treated fields into bodies of water in sufficient quantities to harm fish directly is unlikely. Water contamination through misapplication, cleaning of equipment, disposal of unwanted material or containers, or through effluent from manufacturing and formulating operations must be avoided.

Information presently available is insufficient for an evaluation of possible subacute hazards to freshwater or marine ecosystems from the use of trifluralin.

CASE STUDY NO. 19 CAPTAN

A. Product Description

Chemical Name: N-trichloromethylthio-4-cyclohexene 1,2-dicarboximide

Trade Names: Merpan, Orthocide

Pesticide Class: Fungicide; Chlorinated organo-sulfur compound

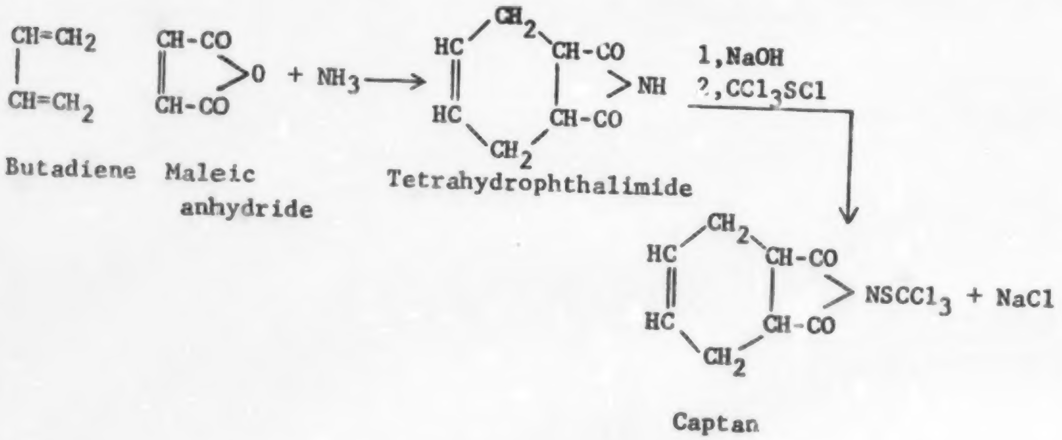
Properties: Solid; nearly insoluble in water; very low toxicity; non-persistent

B. Manufacturers

Name	Plant Location	Plant Capacity	Est. 1972 Prod.
Calhio Chemical	Perry, Ohio	25 million lb (estimated)	17 million lb

C. Production Methods and Waste Control Technology

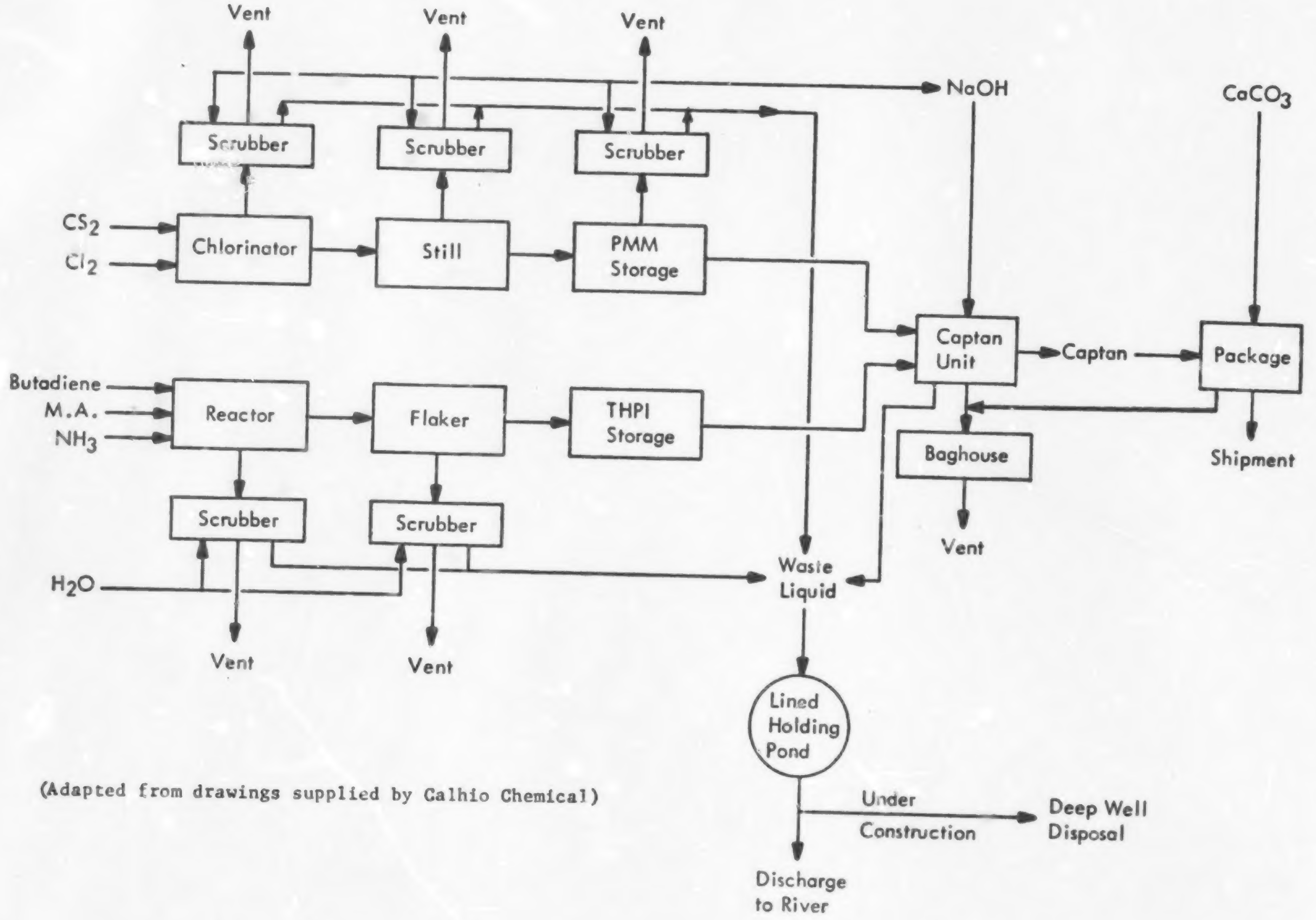
Information on production methods and waste control technology for captan have been reported.[1] The reaction chemistry is:


CH=CH2
CH=CH2
CH-CO
CH-CO
O
+ NH3
CH2
HC
HC
CH-CO
CH-CO
NH
CH2
1,NaOH
2,CCl3SCl
Butadiene
Maleic anhydride
Tetrahydrophthalimide
HC
HC
CH2
CH-CO
CH-CO
NSCCl3
+ NaCl
CH2
Captan

$$CS_2 + 3Cl_2 \xrightarrow{I_2} CCl_3SCl + SCl_2$$

Perchloromethyl mercaptan

A production and waste schematic for captan is shown in Figure 42.


Vent
Vent
Vent
Scrubber
Scrubber
Scrubber
NaOH
CaCO3
CS2
Cl2
Chlorinator
Still
PMM Storage
Captan Unit
Captan
Package
Butadiene
M.A.
NH3
Reactor
Flaker
THPI Storage
Baghouse
Shipment
Scrubber
Scrubber
Vent
H2O
Waste Liquid
Vent
Vent
Lined Holding Pond
Under Construction
Deep Well Disposal
Discharge to River

(Adapted from drawings supplied by Calhio Chemical)

Figure 42 - Production and Waste Schematic for Captan[1/]

The liquid effluents go to an asphalt-lined settling pond where they are retained 6 to 7 days. The effluent from the pond goes to a river and then to Lake Erie. This is monitored weekly and captan is said to by "nil". The sanitary wastes go to a septic tank. The solid wastes (spills, contaminated wastes from floors, etc.) are buried on the plant property, trash paper (cardboard) goes to a local collector, and metal scrap is sold to local scrap dealers. For air pollution control, baghouse stacks, filter hood exhaust, and packer baghouse stacks are used. All materials from clean-up are recovered; dust goes to broken bag handling, lumps are slurried and refiltered, and water goes to the waste system. Captan is manufactured in equipment which is also used in producing folpet (a fungicide). Raw materials are received by tank cars, in drums, and by truck loads (bulk).

D. Formulation, Packaging, and Distribution

The technical product is packaged in 50 lb. paper bags with a polyethylene inner coat and Orlon thread. Ortho, a division of Chevron, has captan available as Orthocide® 80W (80% captan), Orthocide® 50W (50% captan) a wide selection of dusts, and several Orthocide® seed protectants.

E. Use Patterns

General :	Captan was the first phthalimid fungicide to attain widespread commercial use. It has been marketed since about 1950 and has remained the most widely used fungicide in this group to this date. It was welcomed especially by deciduous fruit growers because it is nonphytotoxic and does not adversely affect fruit finish (as many other pesticides do).
Action :	Contact fungicide, broad spectrum; inhibits mycelial growth from germinating fungus spores; protective (not curative) action.
Target Crops :	Apples, peaches, other deciduous fruits; strawberries, grapes, citrus; vegetable crops; protection of seeds (corn, sorghum, peanuts, soybeans, rice, many other crops); ornamentals; commercial and industrial uses.

Target Diseases : Scab; brown, black, blossom end, bitter and other rots; grey mold, leaf spot and other foliar diseases; Pythium and other seed and soil-borne disease organisms.

Application : Foliar spray (or dust) treatments, mostly by ground equipment; seed treatment by dry powder or aqueous suspension (slurry), or in the planter box.

Rates of Application : 0.5-1.0 lb. AI/100 gals. or 4-10 lbs. AI/acre on tree fruits; 2-3 lbs. AI/acre on small fruits and truck crops; 0.8-2.0 ozs. AI/100 lbs. of seed (up to 9.0 ozs. AI/100 lbs. for some seeds).

Frequency : Foliar treatments: 2-6, up to 10 applications per growning season. Seed treatment: Once per season.

Time of Application : Seed treatments prior to planting; foliar treatments throughout the growing season.

Estimated Distribution : All figures in millions of lb AI/year, 1972.

U.S. Production	Imports	Exports	Domestic Consumption
17	Negl.	1	16

Domestic Use by Category and Geographic Region

Region	Agricultural	Industrial/ Commercial	Gov't Agencies	Home & Garden	Totals
NE	3.5				
SE	2.0				
NC	2.0	Negligible	Negligible		
SC	0.5				
W	2.0				
Totals	10.0			6	16

A materials flow diagram for captan is shown in Figure 43.

F. Alternatives

Chemicals : Other phthalimid fungicides including folpet (Phaltan) and captafol (Difolatan); dodine (Cyprex) against apple scab; other organic and some inorganic fungicides.

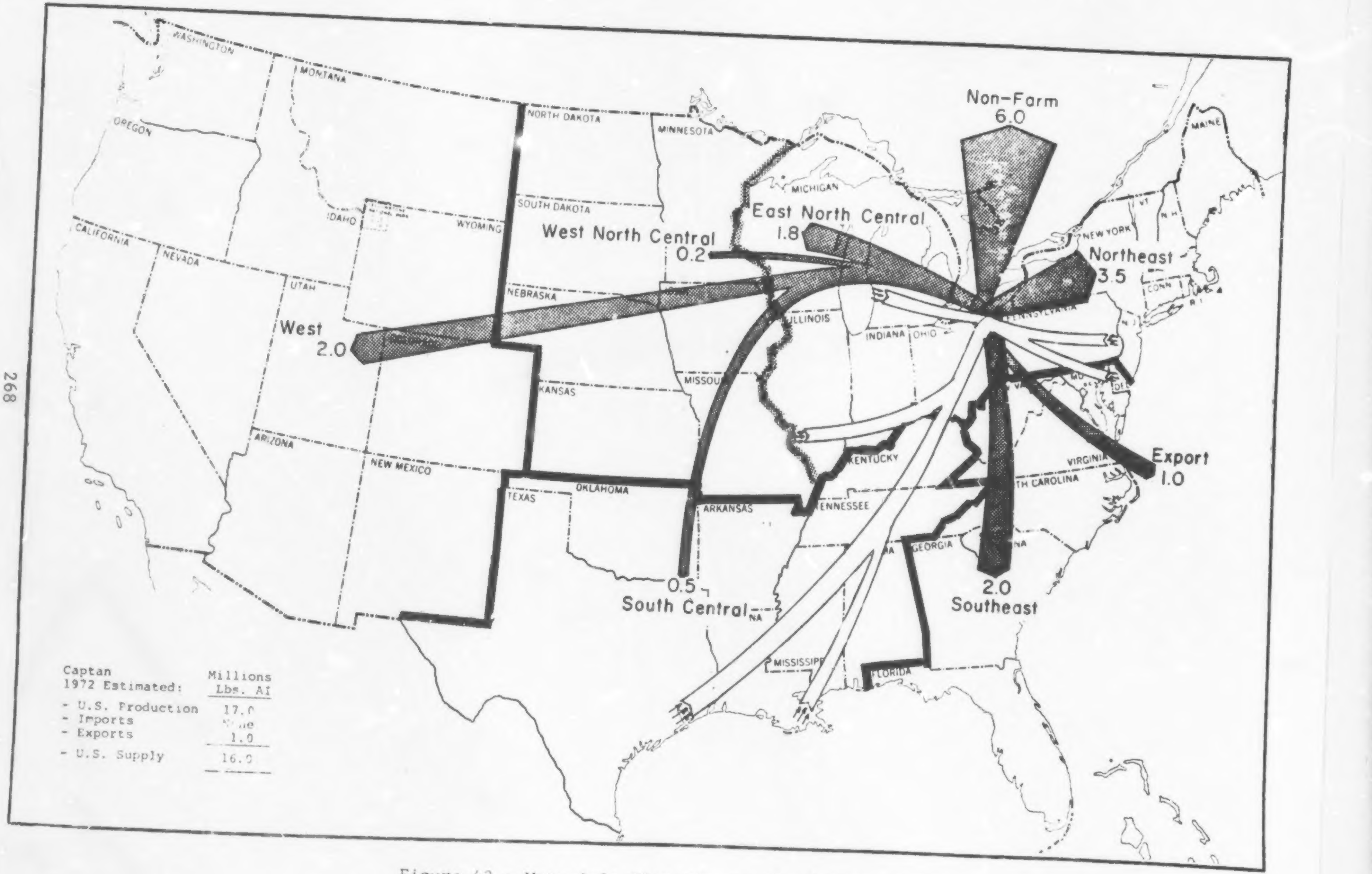

Non-Farm
6.0
Northeast
3.5
Export
1.0
Southeast
2.0
South Central
0.5
East North Central
1.8
West North Central
0.2
West
2.0
WASHINGTON
OREGON
CALIFORNIA
MONTANA
IDAHO
NEVADA
WYOMING
UTAH
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
MISSOU
ARKANSAS
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
GEORGIA
FLORIDA
NA
VIRGINIA
TH CAROLINA
PENNSYLVANIA
NEW YORK
VT
N H
MAINE
CONN
R I
MD
DEL
N J
Captan
1972 Estimated:
Millions
Lbs. AI
- U.S. Production 17.0
- Imports None
- Exports 1.0
- U.S. Supply 16.0

Figure 43 - Materials Flow Diagram for Captan, 1972

Nonchemical : There are no practical nonchemical alternatives for control of the plant diseases controlled by these fungicides.

G. Environmental Impact Potential

Mammalian Toxicity : Captan is relatively nontoxic to laboratory animals by the oral, dermal and inhalation route. The active ingredient is strongly irritating to eyes, moderately irritating to nose and throat, and slightly irritating to the skin. Formulated products and water suspensions are proportionately less irritating. Allergic dermatitis from exposure to captan has been reported by at least one investigator, but does not appear to be a frequent problem. Captan formulations carry the signal word "Caution" on the label.

In chronic toxicity studies, the no-effect level in the diet of rats was 1000 ppm. No cumulative toxic effects have been reported. Residue tolerances for captan have been established for a large number of crops, ranging from 2-100 ppm, 25 ppm for most crops.

In a chicken embryo test, captan was one of three fungicides that showed teratogenic activity. Following these findings, several special studies on the possible embryotoxicity, teratogenicity and mutagenocity of captan were conducted. The results obtained appear to be contradictory at least in part, and are difficult to interpret. Their possible significance in regard to human health has not been conclusively determined.

Nontarget Organisms : Captan is moderately toxic to fishes, relatively nontoxic to birds and wild mammals. No data are available on its possible effects on lower aquatic organisms. In the soil, captan is toxic to some fungi, but relatively nontoxic to many other soil organisms. There are no data on possible build-up in food chains.

Environment : Captan is not persistent. Its fungicidal effectiveness on treated foliage extends for 3-7 days. It may volatilize from treated surfaces to some extent. Its propensity for leaching is low. Surface run-off from

Environment continued	:	target areas in water or on solids is not likely to occur. Captan is degradable in the environment by biological organisms as well as by nonbiological factors. It is rapidly degraded in water, soil, biota, and under akaline conditions. Its half-life in soil is generally less than one month, and there is no problem of residue carryover to the next season.
Evaluation	:	Captan has been in large-scale commercial use worldwide for more than twenty years. It may cause dermatitis to persons handling it. There is no evidence that serious other hazards to human health, or hazards to terrestrial ecosystems outside of target areas are associated with the use of captan as a fungicide.

Data on possible effects of captan on aquatic ecosystems, especially lower aquatic organisms, are insufficient for evaluation of possible hazards. However, captan is not persistent, and migration of captan residues from treated areas to lakes, streams, or ponds in significant quantities is unlikely.

CASE STUDY NO. 20. CREOSOTE

A. Product Description

Creosote is defined by the American Wood Preservers Association as follows: "As used in wood preserving, creosote is a distillate of coal tar produced by high temperature carbonization of bituminous coal. It consists principally of liquid and solid hydrocarbons; it is heavier than water and has a continuous boiling range of at least 125°C, beginning at about 200°C."

No specific component of creosote is responsible for its fungicidal activity. When creosote is fractionated into several narrow-boiling-range components, fungitoxicity can be demonstrated for every fraction. The lower-boiling fractions are more fungicidal than the higher ones, but they lack the residual activity of the higher-boiling fractions and do not give adequate protection over long exposure periods. The more volatile components evaporate, resulting in poor protection.

B. Manufacturers and Plant Locations

Creosote is produced by the distillation of coal tar, which in turn is obtained from the coking of coal. Almost all of the creosote produced is used by companies engaged in the preservation of wood. Thus, three types of manufacturers must be considered: coal tar producers, coal tar distillers and wood preservation plants.

1. Producers of coal tar: The 64 coal tar producers in the U.S. (1972) are listed in Table XXXII and a map showing their location is presented in Figure 44. Four producers of coal tar also produce creosote, i.e., U.S. Steel, Koppers, Allied Chemical and Great Lakes Steel.

2. Producers of creosote: The 24 creosote production plants are listed in Table XXXIII. A map showing their location is presented in Figure 45. Koppers and Western Tar Products are creosote producers engaged in the preservation of wood.

3. Wood preservation plants: The wood preserving industry in the United States is composed of more than 400 treating plants, of which about 200 handle creosote. Most of the plants are concentrated in two distinct regions. The larger region extends from East Texas to Maryland and corresponds roughly to the natural range of the southern pines, the major species utilized.

TABLE XXXII[76]

COAL TAR PRODUCERS IN THE UNITED STATES ON DECEMBER 31, 1972

Name	Location of Palnt	Coal-Chemical Materials Produced[a]
ALABAMA		
1. Alabama Byproduct Corporation	Tarrant	1,5,13
2. Republic Steel Corporation	Gadsden	1,5,13,14,15,16,17,19
3. Republic Steel Corporation	Thomas	1,5,13,14,17,19
4. Empire Coke Company	Holt	1,5,7,13,18
5. U.S. Pipe and Foundry Company	Birmingham	1,5,13,18
6. U.S. Steel Corporation	Fairfield	1,5,6,12,13,19
7. Woodward Iron Company	Woodward	1,5,13,14,15,16,17,19
CALIFORNIA		
8. Kaiser Steel Corporation	Fontana	3,5,9,13,18
COLORADO		
9. Colorado Fuel and Iron Steel Corporation	Pueblo	1,2,3,5,6,12,13,14,15, 16,17,19
ILLINOIS		
10. Granite City Steel Company	Granite City	1,5,13,18
11. Interlake, Inc.	Chicago	1,5,13,19
International Harvester Company	Chicago	1,5,13
Republic Steel Corporation	Chicago	1,5,8,13,19

TABLE XXXII (Continued)

Name	Location of Plant	Coal-Chemical Materials Produced[a]
INDIANA		
12. Bethlehem Steel Corporation	Burns Harbor	1,5
13. Citizens Gas and Coke Utility	Indianapolis	5
14. Indiana Gas and Chemical Corporation	Terre Haute	5,13,14,15,16,17
15. Inland Steel Company	Indiana Harbor	1,5,8,13
Youngstown Sheet and Tube	Indiana Harbor	2,5,13,18
16. U.S. Steel Corporation	Gary	1,5,6,12,13,17,19
KENTUCKY		
17. Allied Chemical Corporation	Ashland	2,5,7,13
MARYLAND		
18. Bethlehem Steel Corporation	Sparrows Point	1,5,13,14,15,16,18
MICHIGAN		
19. Allied Chemical Corporation	Detroit	5
20. Ford Motor Company	Rouge	3,5,13
21. Great Lakes Steel Corporation	Zug Island	1,5,8,13
MINNESOTA		
22. Koppers Company, Inc.	St. Paul	5

TABLE XXXII (Continued)

Name	Location of Plant	Coal-Chemical Materials Produced[a/]
MINNESOTA (Concluded)		
23. U.S. Steel Corporation	Duluth	1,5
MISSOURI		
24. Great Lakes Carbon Corporation	St. Louis	5
NEW YORK		
25. Allied Chemical Corporation	Buffalo	2,5,7,13
Donner-Hanna Coke Corporation	Buffalo	1,5,8,13
26. Bethlehem Steel Corporation	Lackawanna	1,5,8,13,18
OHIO		
27. Allied Chemical Corporation	Ironton	2,5,7,13
28. Armco Steel Corporation	Hamilton	1,5,13
29. Armco Steel Corporation	Middletown	1,5,8,13,14,15,16,17,18
30. Diamond Shamrock Corporation	Painesville	2,5
31. Empire Detroit Steel Corporation	Portsmouth	5,13
32. Interlake, Inc.	Toledo	1,5,13,14,15,16
33. Republic Steel Corporation	Cleveland	1,5,8,13,14,15,16,17,19
34. Republic Steel Corporation	Massillon	1,5,13

TABLE XXXII (Continued)

Name	Location of Plant	Coal-Chemical Materials Produced[a]
OHIO (Concluded)		
35. Republic Steel Corporation	Warren	1,5,13,19
36. Republic Steel Corporation	Youngtown	1,5,13,14,15,16,17,19
37. Youngstown Sheet and Tube Company	Campbell	1,5,13
38. U.S. Steel Corporation	Lorain	1,5,13
PENNSYLVANIA		
39. Alan Wood Steel Company	Swedeland	5,13,14,17
40. Bethlehem Steel Corporation	Bethlehem	1,5,13,14,15,16,18,19
41. Bethlehem Steel Corporation	Johnstown	1,5,7,12,13,17,18
42. Crucible Steel Corporation	Midland	1,5,8,13
43. Eastern Gas and Fuel Associates	Philadelphia	5
44. Interlake, Inc.	Erie	5
45. Jones and Laughlin Steel Corporation	Aliquippa	1,5,8,13,14,15,16,17
46. Jones and Laughlin Steel Corporation	Pittsburgh	1,5,8,13
47. Wheeling-Pittsburgh Steel Corporation	Monessen	1,5,8,13
48. Shenango, Inc.	Neville Island	1,5,8,13
U.S. Steel Chemical Company	Neville Island	6

TABLE XXXII (Continued)

Name	Location of Plant	Coal-Chemical Materials Produced[a]
PENNSYLVANIA (Concluded)		
49. U.S. Steel Corporation	Clairton	1,5,6,9,10,11,12,13, 14,15,16,17,19,21,22
50. U.S. Steel Corporation	Fairless	1,5,8,13,19
TENNESSEE		
51. Woodward Iron Company Chattanooga Division	Alton Park	1,5,13,14,15,16
TEXAS		
52. Armco Steel Corporation	Houston	5,13,14,15,16,18
53. Lone Star Steel Company	Daingerfield	1,5,13,14,15,16,17
UTAH		
54. U.S. Steel Corporation	Geneva	1,5,13,14,15,16,17
WEST VIRGINIA		
55. National Steel Corporation	Weirton	1,5,7,8,13,18
56. Sharon Steel Corporation	Fairmont	1,5,8,13
57. Wheeling-Pittsburgh Steel Corporation	East Steubenville	1,5,7,8,12,13
WISCONSIN		
58. Milwaukee Solvay Coke Division Pickands Mather	Milwaukee	5

TABLE XXXII (Concluded)

Name	Location of Plant	Coal-Chemical Materials Produced[a]
PENNSYLVANIA		
59. Carpentertown Coal and Coke Company	Mahoning	5
60. Bortz Coal Company	Daugherty	5
61. Ruane Coal and Coke Company	Laughead	5
62. Shenango, Inc.	Lucerne	5
VIRGINIA		
63. Christie Coal and Coke Company	Esserville	5
64. Jewell Smokeless Coal Corporation	Vansant	5

---

[a] Coal-chemical materials produced at coke plants are designated as follows:

1 - Ammonium sulfate
2 - Ammonia liquor (NH_3 content)
3 - Diammonium phosphate
4 - Monoammonium phosphate
5 - Crude coal tar
6 - Creosote
7 - Crude chemical oil (tar acid oil)
8 - Sodium phenolate or carbolate
9 - Phenol
10 - Cresols
11 - Cresylic acid
12 - Pitch-of-tar
13 - Crude light oil
14 - Benzene
15 - Toluene, all grades
16 - Xylene, all grades
17 - Solvent naphtha, all grades
18 - Intermediate light oil
19 - Naphthalene
20 - Pyridine
21 - Picolines
22 - Sulfur

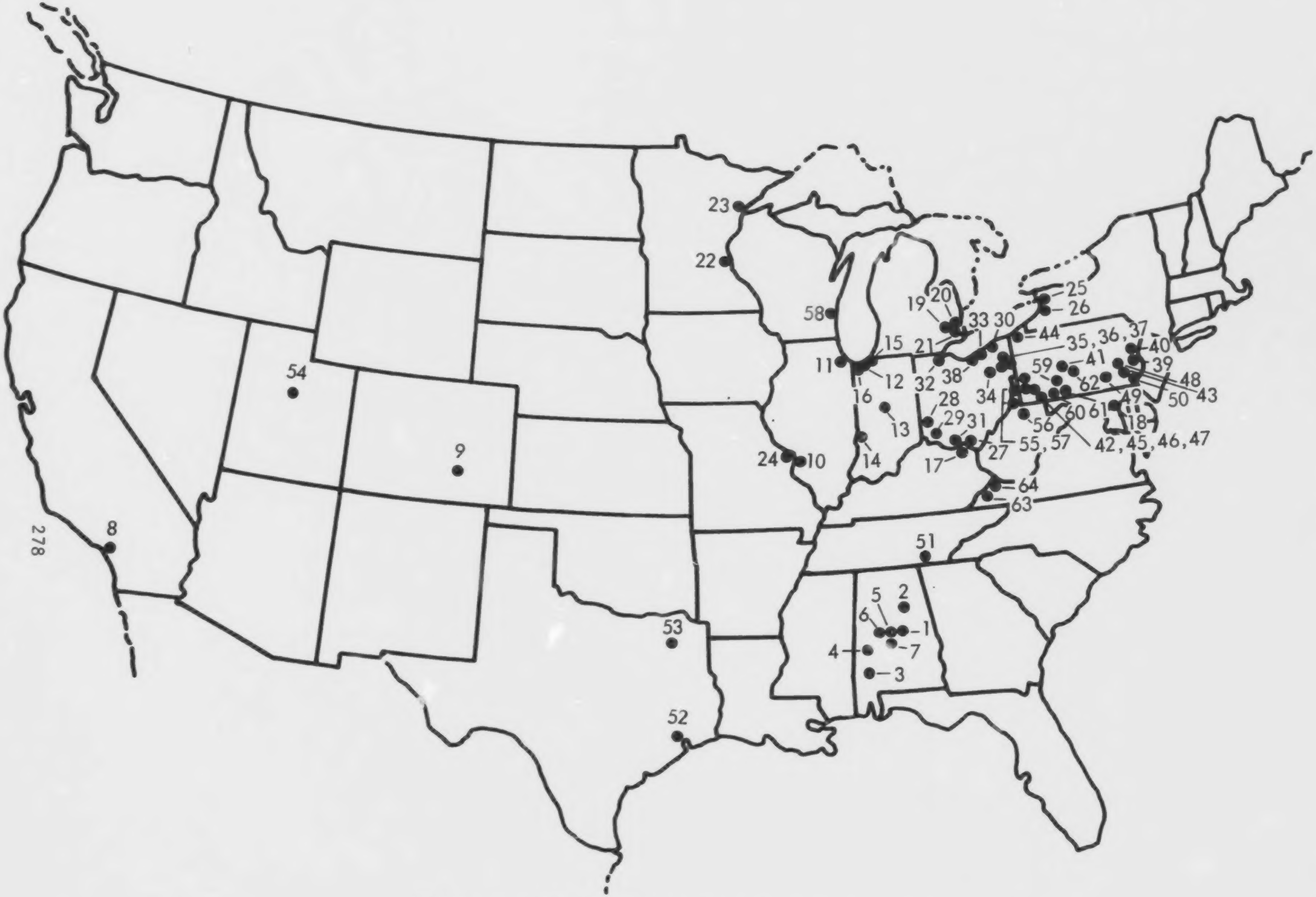

23
22
58
54
9
8
24
10
11
15
12
16
13
14
19
20
33
30
21
32
38
28
29
31
34
17
27
25
26
44
35,36,37
40
39
59
41
62
48
50
43
49
56
60
61
18
55,57
42,45,46,47
64
63
51
2
5
6
1
7
4
3
53
52

Figure 44 - Coke Plants in the United States (1972)

TABLE XXXIII

CREOSOTE PRODUCTION PLANTS IN THE U.S.[77]

	Estimated Plant Capacity[a] (million lb/year)	Estimated Annual Production[a] (million lb)
Allied Chemicals Corporation		
Detroit, Michigan	100-200	250-350
Ensely, Alabama	100-200	
Ironton, Ohio	100-200	
Koppers Company, Inc.		350-450
Cicero (Chicago), Illinois	100-200	
Follansbee, West Virginia	100-200	
Fontana, California	200-300	
Houston, Texas	10-20	
Portland, Oregon	10-20	
Kearny (Seaboard), New Jersey	10-20	
St. Paul, Minnesota	10-20	
Swedeland, Pennsylvania	10-20	
Woodward, Alabama	100-200	
Youngstown, Ohio	100-200	
Reilly Tar and Chemical Corporation		50-100
Cleveland, Ohio	10-20	
Granite City, Illinois	10-20	
Ironton, (Provo) Utah	10-20	
Lone Star, Texas	10-20	
Chattanooga, Tennessee	10-20	
USS Chemicals		250-350
Clairton, Pennsylvania	100-300	
Fairfield, Alabama	100-200	
Gary, Indiana	100-200	
The Western Tar Products Corporation		20-40
Memphis, Tennessee	10-20	
Terre Haute, Indiana	10-20	
Witco Chemical Corporation		10-20
Point Comfort, Texas	10-20	
Total Annual Production (1972)		1,150[a]

---

[a] MRI estimates.

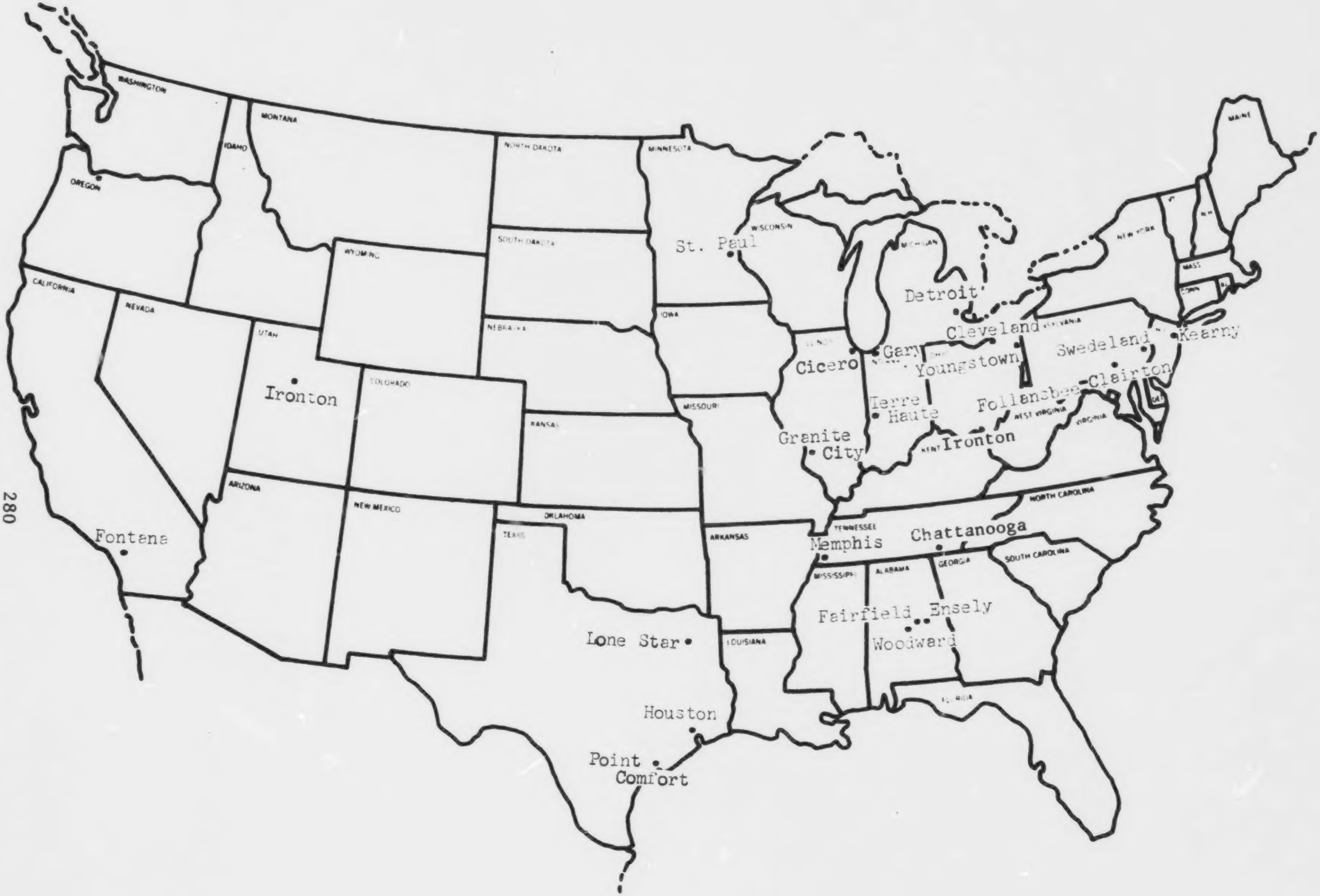

WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
KENT
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
NEW YORK
MASS
CONN
MAINE
Fontena
Ironton
St. Paul
Cicero
Gary
Detroit
Cleveland
Youngstown
Swedeland
Kearny
Clairton
Follansbee
Terre Haute
Granite City
Ironton
Memphis
Chattanooga
Fairfield
Ensely
Woodward
Lone Star
Houston
Point Comfort

Figure 45 - Creosote Production in Plants in the U.S. (1972)

The second concentration of plants is located along the Pacific Coast, where Douglas fir and western red cedar are the species of primary interest to the industry. About 77% of the United States' plants are located in these two regions. A distribution of plants by type and location is presented in Figure 46.

C. Production Methods and Waste Control Technology

1. Production methods:

a. Coal tar: Coal tar is produced by the carbonization or coking of coal, i.e., heating the coal at high temperatures (1650-2150°F) in the absence of air. The major product of this process is coke, which is used in the production of pig iron. Coke represents about 75% of the total value of products obtained through coal carbonization. The major products of the coking process are listed in Table XXXIV.

TABLE XXXIV

PRODUCTS FROM THE CARBONIZATION OF 1 TON OF COAL

Products	
Coke	1,300-1,500 lb
Coal tar	8-10 gal.
Light oil	3 gal.
Ammonia	5-6 lb
Coal gas	9,500-11,500 ft^3

Annual coal tar production in the United States amounts to over 8.5 billion pounds per year. About 75% of the coal tar (about 6.3 billion pounds) is subjected to distillation, and about 25% of the tar is ordinarily consumed by the steel industry as fuel. (Because of the energy shortage, a much larger proportion of coal tar may be used as fuel by the steel industry.)

b. Creosote: Creosote is produced by the distillation of coal tar (Figure 47). A number of distillate oils are produced in the distillation of coal tar (Table XXXV) and creosote is a mixture of these oils, blended to meet specialized (cf. product description) requirements.

The larger tar distillation operations (100 to 700 tons/day) employ continuous distillation processes. However, at the present time, most tar distillation plants employ batch distillation processes.

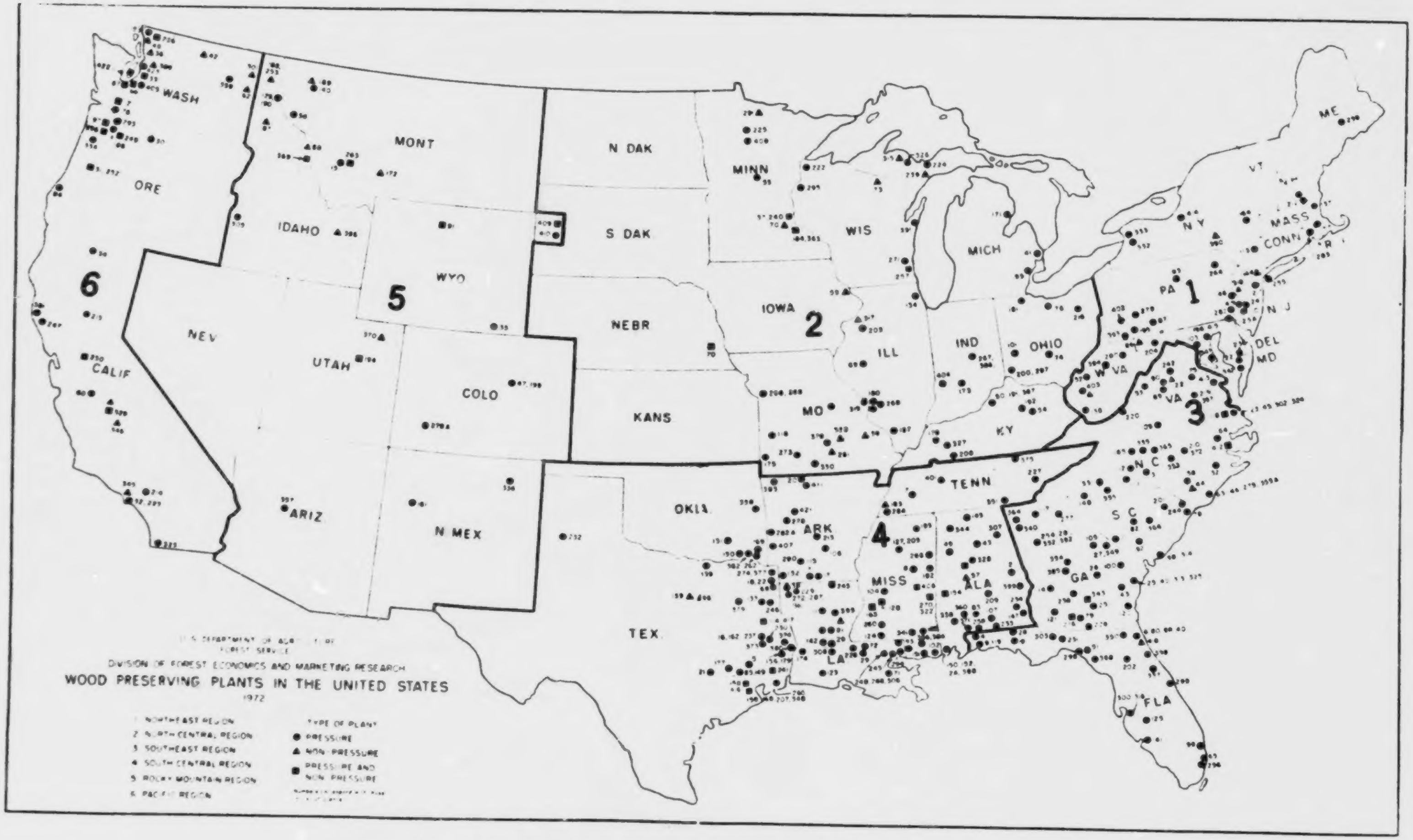

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
DIVISION OF FOREST ECONOMICS AND MARKETING RESEARCH
WOOD PRESERVING PLANTS IN THE UNITED STATES
1972
1 NORTHEAST REGION
2 NORTH CENTRAL REGION
3 SOUTHEAST REGION
4 SOUTH CENTRAL REGION
5 ROCKY MOUNTAIN REGION
6 PACIFIC REGION
TYPE OF PLANT
● PRESSURE
▲ NON-PRESSURE
■ PRESSURE AND NON-PRESSURE
1
2
3
4
5
6
WASH
ORE
CALIF
IDAHO
MONT
NEV
UTAH
ARIZ
WYO
COLO
N MEX
N DAK
S DAK
NEBR
KANS
OKLA
TEX
MINN
IOWA
MO
ARK
LA
WIS
ILL
MISS
MICH
IND
OHIO
KY
TENN
ALA
GA
FLA
S C
N C
VA
W VA
PA
N Y
VT
ME
MASS
CONN
R I
N J
DEL
MD

Figure 46 - Wood Preserving Plants in the United States (1972)78/

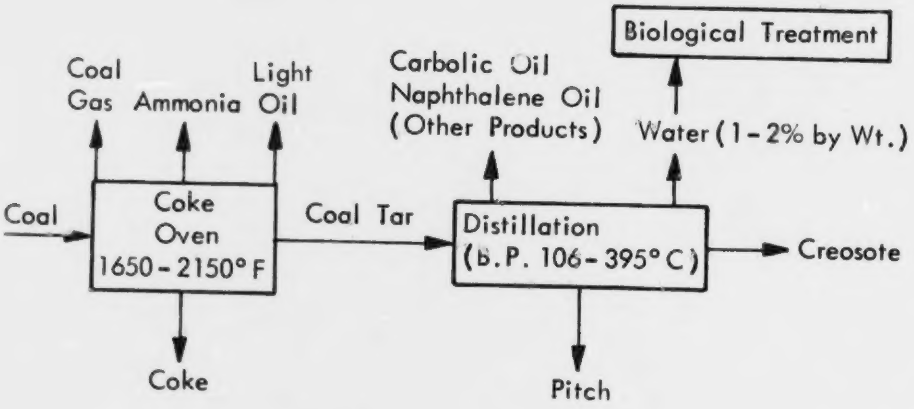

Biological Treatment
Coal Gas
Ammonia
Light Oil
Carbolic Oil
Naphthalene Oil
(Other Products)
Water (1-2% by Wt.)
Coal
Coke Oven 1650-2150° F
Coal Tar
Distillation (B.P. 106-395° C)
Creosote
Coke
Pitch

Figure 47 - Production and Waste Schematic for Creosote

TABLE XXXV

TYPICAL FRACTIONS TAKEN IN CONTINUOUS TAR DISTILLATION[79]

Fraction No.	Names	Boiling Range (°C)	Weight Percentage of Crude Tar
1	crude benzole, light oil	106-107	2.4
2	naphtha, carbolic oil, phenolic oil	167-194	3.1
3	heavy naphtha, carbolic oil, naphthalene oil	203-240	9.3
4	naphthalene oil	215-254	3.5
5	wash oil benzole absorbing oil, light creosote	238-291	10.2
6	creosote	271-362	11.5
7	heavy creosote, heavy oil	285-395	12.1
residue	medium-soft pitch		40.5
liquor and losses			7.4

(c) Wood preservation: Practically all of the creosote produced in this country is used by commercial organizations for the preservation of wood. A brief description of the wood preservation industry was presented in Chapter IV of this report.

2. Waste control technology: The most important pollution problems related to creosote are associated with the wood-treatment processes. Therefore, major emphasis will be placed on waste control problems associated with this phase of creosote operations.

a. Waste control technology in the production of coal tar and creosote: The pollution potential in the production of coal tar is much greater than it is for the production of creosote. The reason for this is the fact that creosote production is a distillation process which is performed essentially within a closed system.

An appreciable quantity of water is in coal tar (1-2% of the total volume) that is boiled off in the distillation process and is disposed of along with other process waters. In some of the larger tar distillation plants, the aqueous wastes are treated in the company's biological treatment plant. At other plants, the wastes are discharged to the municipal system. Thus, nearly all effluents receive biological treatment of some kind.

Apparently, no special types of microorganisms are required for the treatment of wastewaters containing creosote. However, microorganism populations which are subjected to wastewaters of this kind most probably adapt in order to metabolize the waste. Wastewater treatment plants at tar distillation facilities are generally not started with municipal sludges, but are ordinarily started with river water that has been exposed to this type of material. Thus, the microorganisms are already partially acclimated to the metabolism of creosote-like materials. Furthermore, a long startup period generally allows the microorganisms population to adjust to the metabolism of this type of waste. In order to maintain continuity in the composition of the waste stream, the aqueous waste is held in large holding tanks. Industry representatives knew of no instance in which microorganisms populations have been destroyed by an excessive quantity of creosote-containing waste materials.

Tar distillation plants have little material to dispose of other than water; all distillates are sold or burned for fuel, and the distillation residue, pitch, is also sold. Fume collection systems are used at locations where hot pitch is loaded into tank cars, and at certain other areas where fume control is necessary. The materials scrubbed from the air is recycled. For example, creosote is frequently employed in the air scrubbing operations, and the absorbed materials remain in the creosote.

Highly efficient oil scrubbers of this type are required in order to keep the pitch fume components at a concentration of less than 0.2 mg/m^3, the OSHA standard. Equipment of this type is not required in the tar unloading operations because the tar is not hot enough to fume. Thus, the pitch handling operations are the major areas where this type of treatment is required. Creosote does not have to be very hot in order to be fluid, and therefore, fume control operations are not required in the handling of creosote. Creosote is normally handled at 125-150°F, and at this temperature, would not emit an objectionable amount of fumes.

b. Waste control technology in the preservation of wood with creosote: Wood preservation processes can be classified as "pressure" or "nonpressure" processes depending upon whether or not air and/or hydrostatic pressure and vacuum is employed to assist in impregnating the wood with preservative. Over 80% of wood treatment plants employ pressure processes. The various processes are described below and a processing and waste treatment schematic is presented in Figure 48.

(1) Nonpressure processes: Nonpressure processes utilize open tanks and either hot or cold preservatives in which the stock to be treated is immersed. Employment of this process on a commercial scale to treat timbers and poles with creosote is largely confined to the Rocky Mountain and Pacific regions, especially the latter. Nonpressure processes for treating wood with pentachlorophenol are located in Minnesota as well as in the Rocky Mountain and Pacific regions. Nonpressure processes for treating lumber and posts with creosote are located primarily in the East, but pentachlorophenol is used extensively throughout the country for dip treating in farming and ranching areas, particularly in Missouri, Texas, Idaho, Montana and South Dakota.

The volume of wastewater originating from nonpressure processes is small and consists principally of precipitation that enters the open tanks employed.

(2) Pressure processes: Plants that employ pressure processes have a more serious pollution problem. Their effluents are normally characterized by a high phenol content and a high oxygen demand, the latter due to entrained oils and various extractives, principally carbohydrates, that are removed from wood during pretreatment "conditioning." There are two types of conditioning processes, and their use depends primarily upon the species or wood being treated. The Boulton process is the predominant conditioning method used at plants which treat Douglas fir and other westcoast species; open steaming is the predominant method used with pines and other species native to the East.

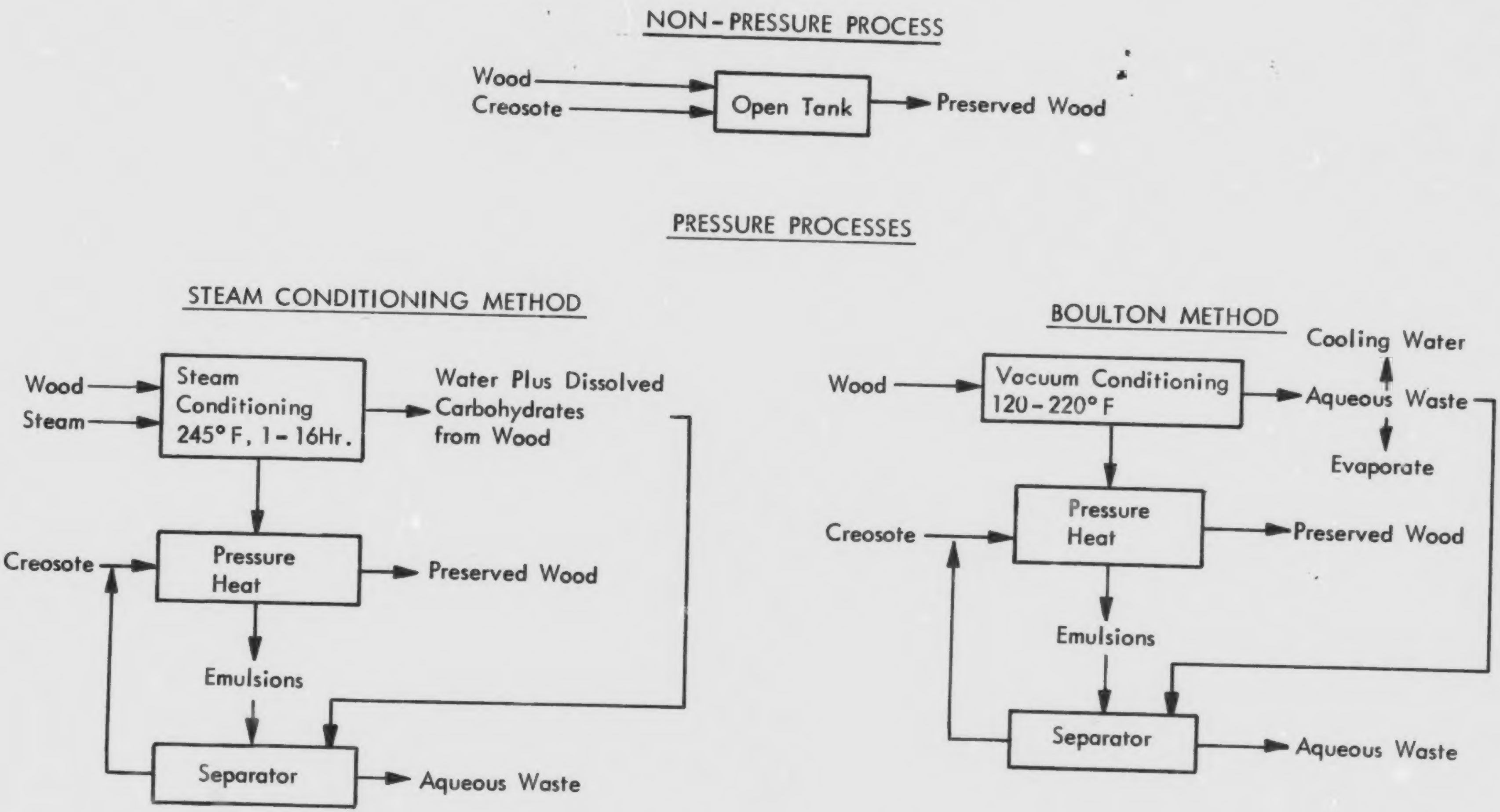

NON-PRESSURE PROCESS
Wood
Creosote
Open Tank
Preserved Wood
PRESSURE PROCESSES
STEAM CONDITIONING METHOD
Wood
Steam
Steam Conditioning 245° F, 1-16Hr.
Water Plus Dissolved Carbohydrates from Wood
Creosote
Pressure Heat
Preserved Wood
Emulsions
Separator
Aqueous Waste
BOULTON METHOD
Wood
Vacuum Conditioning 120-220° F
Cooling Water
Aqueous Waste
Evaporate
Creosote
Pressure Heat
Preserved Wood
Emulsions
Separator
Aqueous Waste

Figure 48 - Production and Waste Schematic for Wood Treatment Processes

Steam conditioning: When it is either impracticable or undesirable to air-season southern pine timber before subjecting it to pressure treatment, a steaming and vacuum process is often employed to condition the wood. This involves steaming the timber in the treating cylinder for several hours, usually at 245°F or less. Following this treatment a vacuum is drawn on the charge for 1 hr or more. This process results in some loss of moisture from green timber and apparently has other effects, not well understood, which cause the wood to take suitable treatment even though its moisture content is still relatively high. Partially, or even thoroughly, seasoned material may also be subjected to such treatment, especially when it is desired to sterilize the wood by heating. Although its present use is limited mainly to southern pine, steam and vacuum conditioning is also applicable to some other softwood species.

The waste stream is composed of both the steam condensate that forms in the retort and water derived from the wood. The volume is usually large relative to that for the Boulton process, and the waste usually has a much higher oxygen demand because of emulsified oils and dissolved solids. Elimination of discharges from plants of this type is not practicable. The waste is amenable to conventional wastewater treating methods, however, and the volume of discharge can be reduced substantially by in-plant process changes and control techniques.

The Boulton process: West Coast species, such as the Douglas fir, are conditioned for the same purposes as above by the Boulton process, in which the wood is heated under vacuum in the preservative at 180 to 220°F prior to preservative injection. Wastewater consists only of water removed from the wood, and when the volume is relatively small (amounting to less than 2,500 gal/day at most plants) it can be reused as cooling water and disposed of by evaporation. A zero discharge of process water has already been achieved by many plants that employ the Boulton method of conditioning. When the wastewater volume is relatively high (10,000 gal/day or more), as in the Boulton drying of green piling and poles, treatment methods other than evaporation are required.

Clarification of wastewater: In both types of pressure processes, creosote must be removed from the wastewater. The formation of emulsions greatly complicates this separation procedure. However, much progress has been made recently in solving the emulsion problem. A few years ago, many wood treatment plants discharged the milky white emulsions as wastewater. This is apparently rarely done today in the better plants. The emulsion problem has been solved by a combination of methods. For example, emulsions are markedly reduced by using low-speed, high-volume pumps instead of high-speed, low-volume pumps. Emulsions have been broken by the use of flocculating agents that are subsequently removed by filtration through sand or by settling.

Water-soluble materials cannot be removed by these procedures; however, phenols are somewhat soluble in water, and untreated wastewater may contain 800 to 900 ppm of phenolic material. After flocculation and sand filtration, an average phenol concentration of 150 ppm can be achieved and 400 ppm maximum concentrations of phenol are observed.

D. Formulation, Packaging and Distribution

1. Formulation: Only about 0.1 to 0.2% of the total amount of creosote produced is sold to individuals. This product is a special "crystal free" material, formulated in such a manner that no solid materials will form when the product is cooled to 40°F.

Most of the "crystal free" creosote is sold to farmers or other persons who use the product to preserve wood by treating it themselves. The consumer product can be applied like paint and is considerably more convenient to use than regular creosote. The "crystal free" product is sold in truck quantities, but is also packaged in 55-gal. drums and 5-gal. pails. The product is also repackaged by other companies; apparently the smallest quantity sold to consumers is a 1-gal. container.

The overwhelming majority of the creosote (> 99%) is sold to wood preservation plants. The specifications for this product were presented at the beginning of this case study.

2. Distribution:

a. Coal tar: Coal tar is received by the distilling plant in barges, tank cars, and tank trucks. Tank trucks are used when the coke plant is not far away. If the plants are very near, the tar can be piped from the coking plant to the tar distillation plant.

b. Creosote: Much of the creosote produced is shipped by barge to storage facilities or "terminals." A large storage facility can accommodate a million gallons or more, whereas a "small" facility may contain 100,000 gal. Storage facilities are located on or near major river routes, e.g., at Good Hope, Louisiana; Wilmington, North Carolina; and Lake Charles, Louisiana. The transfer between barge and storage facility is accomplished by means of pipelines.

Terminals have dedicated facilities, and contracts are written to maintain the quality of the product during storage. Terminals do not package products, but act as agents in the storage and distribution of creosote.

From the storage facility, creosote is transported to the wood processing plants, mostly by tank cars. Some creosote is directly transported from the distillation plants to the wood processing plants by barge, tank car or tank truck.

If allowed to cool during shipment, some of the constituents of the creosote are deposited as solids. In this case, heating of the shipping containers is required prior to discharge.

In transit, creosote would contaminate most other products, except materials such as No. 6 fuel oil. However, creosote itself can become contaminated with other products, such as oil, to such an extent that it would not meet AWPA standards. Thus, in the transport of creosote by barge, tank car or tank truck, certain precautions must be taken; either the equipment is dedicated or measures are taken to see that the "empty" container does not contain significant amounts of contaminating material.

Barges are ordinarily owned by barge lines. However, the barges are not dedicated to creosote movement. Barges are ranked according to the extent to which they have become contaminated. A new barge is used only for relatively valuable materials and eventually becomes dirtier and dirtier. Finally, it can only be used for such products as creosote or No. 6 fuel oils or other materials of that kind.

The tank cars and tank trucks which transport creosote are almost exclusively owned by the coal tar distillers and are dedicated to the shipment of creosote. When the cars or trucks are emptied, steam is circulated through heating coils to increase the temperature of the creosote and allow it to flow at a faster rate. When residues build up, they are cleaned out at cleaning stations by circulating high temperature steam through the heating coils, with creosote in the tank. The wash creosote is recovered and then recycled through the distillation step. Thus, in the cleaning of these tanks, no polluted water is generated.

E. Use Patterns

Creosote is used almost exclusively for the protection of wood against attack by fungi, marine borers, or insects. In 1972 almost 275 million cubic feet of wood was treated with preservative or fire retardant materials. More than half of this wood was treated with creosote and creosote-containing mixtures.

Almost 1 billion pounds of creosote were used in these applications. Creosote and creosote-containing solutions were used almost exclusively in the treatment of railroad ties and marine pilings. More than one-third of all wood telephone and telegraph poles were treated with creosote.

Creosote and creosote-coal tar solutions are also used for the preservative treatment of fence posts, marine and foundation piling, wood blocks and timbers for buildings, tanks, bridges, and other structures.

The quantities of wood products treated with creosote in the U.S. are shown in Table XXXVI. The usual treatment rates are 8 to 11 lb of creosote per cubic foot of wood.

A significant quantity of the creosote produced is consumed as fuel by steel producers. The fuel shortage has resulted in an increase in the amount of creosote used in this manner. Both coal tar and creosote can be used as carbon sources in the reduction of iron ore. Industry sources indicate that as much as half of the creosote produced by distillers who are also steel producers could be consumed this winter in this manner.

TABLE XXXVI

WOOD PRODUCTS TREATED WITH CREOSOTE IN THE UNITED STATES[78]

Wood Product	Quantity Treated (millions of cubic ft)
Railroad crossties	85.7
Utility poles	26.4
Lumber and timber	12.9
Fence posts	7.3
Marine pilings	13.6
Switch ties	5.9
Cross arms	0.4
Other	2.1
	154.3

Most available use figures for creosote provide a geographical distribution pattern based upon the amounts of creosote consumed at the wood treatment plant. However, since the ultimate location of the creosote is of interest, an estimate was made on this project of the quantity of preserved wood used in each region. This estimate was based upon AWPA figures and two assumptions: (1) that the amount of creosote used in railroad ties is proportional to the railroad mileage; and (2) that the amount of creosote used in utility poles was proportional to the population. The estimated distribution for creosote is presented below:

Estimated distribution: (All figures in millions of pounds AI per year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
990	160	--	972 Wood preservation
			178 Burned as fuel
			1,150 Total

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	0.5	165			
SE	0.3	145			
NC	0.6	300			
SC	0.3	185			
NW	0.3	90			
SW		85			
Totals	2.0	970	Negligible	Negligible	972

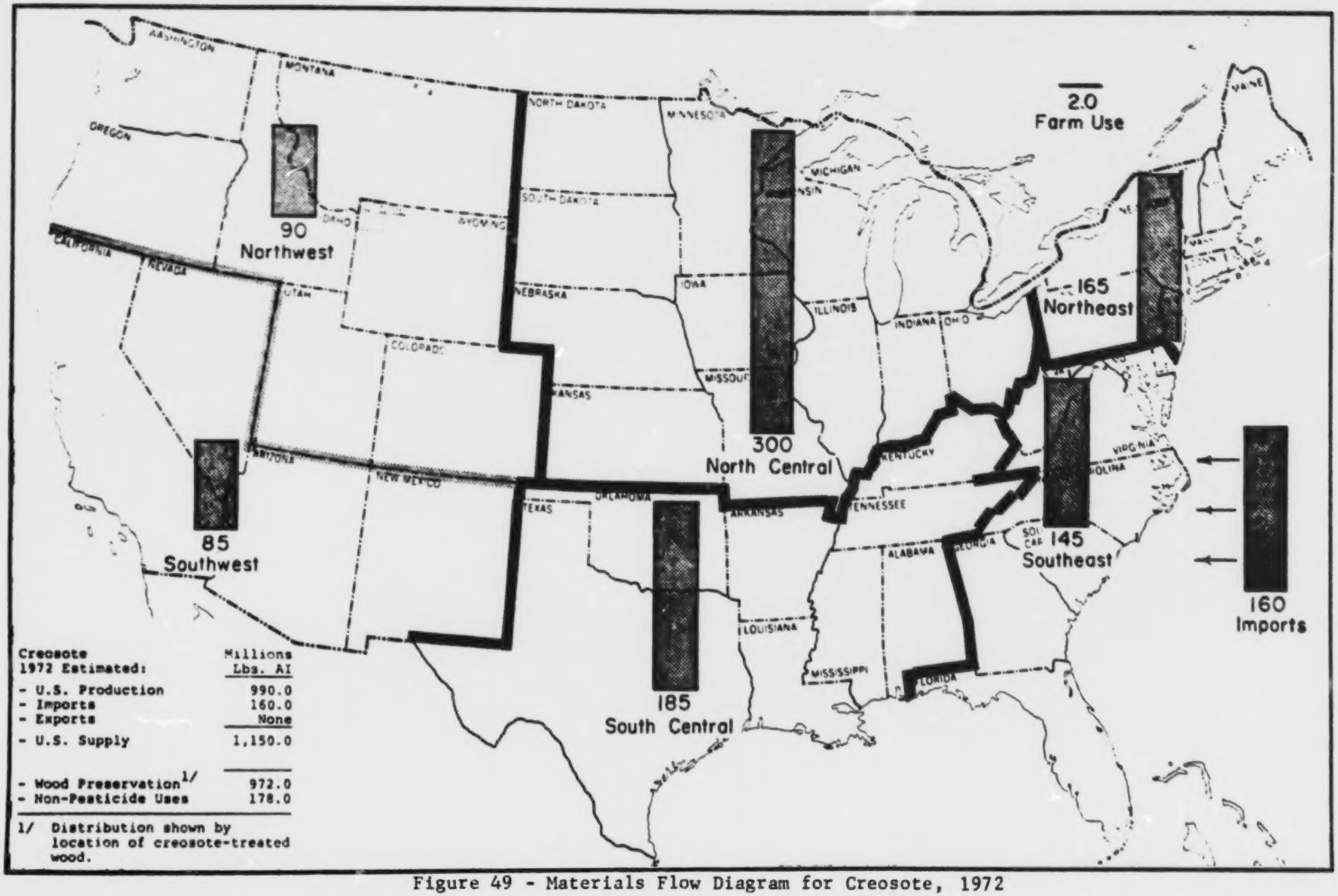
A materials flow diagram for creosote is shown in Figure 49.

F. Alternatives

Creosoted wood in ground contact has at least five times the useful life of wood. Wood, because of its strength, resilience, mechanical wearing ability and economy, is an ideal product to use for cross ties, utility poles, pole-type building structures, highway guard posts and fence posts. The use of untreated wood for these purposes would result in excessive use of forest lands and greatly increased labor and replacement costs.

Creosote's main competitor in the wood preservation market is pentachlorophenol. Penta has encountered wide success in the treatment of utility poles and could possibly be used in treating crossties, except for two considerations.

One is engineering tradition, which is not known for swiftness of change. Creosote has time on its side.


2.0
Farm Use
90
Northwest
85
Southwest
300
North Central
185
South Central
165
Northeast
145
Southeast
160
Imports
WASHINGTON
OREGON
CALIFORNIA
NEVADA
MONTANA
IDAHO
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
VIRGINIA
SOUTH CAROLINA
MAINE

Creosote 1972 Estimated:	Millions Lbs. AI
- U.S. Production	990.0
- Imports	160.0
- Exports	None
- U.S. Supply	1,150.0
- Wood Preservation[1/]	972.0
- Non-Pesticide Uses	178.0

1/ Distribution shown by location of creosote-treated wood.

Figure 49 - Materials Flow Diagram for Creosote, 1972

The second--and most important--is that creosote permeates the wood fibers and has a lubricating effect on the crossties, which aids in preventing their ends from "brooming out." In the eyes of the railroads, a "broomed out" crosstie is worthless.[80]

Penta, on the other hand, is said to preserve crossties by forming an encrustation on their surface and reportedly does not exert an appreciable lubricating effect, according to creosote suppliers.

Creosote is not as desirable as pentachlorophenol in the treatment of utility poles because creosote treatment leaves the poles "dirty" and soils linemen's clothes. Some wood treated with penta can also be painted (depending on the type of petroleum carrier used), whereas creosote treated wood cannot.

Preserved wood products also face continuing competition from nonwood products. As in most such situations, there are advantages and disadvantages to each product in addition to price differentials. However, prices of wood products are strongly influenced by the prices of substitute products and tend to be set slightly below the substitute if there is strong competition.

Table XXXVII lists some of the preserved wood products and their potential substitutes. There is more competition for some uses than in others. Wood piling, for example, is only used for loads up to 50 tons. In some applications, such as building shingles, the aesthetic qualtiy of the wood makes it a premium product which can be sold above the price of competitive products.

TABLE XXXVII

PRESERVED WOOD PRODUCTS AND THEIR SUBSTITUTES[81]

Preserved Wood Product	
Piling	In-place concrete Driven concrete Steel piling Hollow I beams
Marine piling	In-place concrete Driven concrete Interlocking iron sheets
2 x 4's, etc.	Metal tubing
Plywood	Concrete Cinder block
Fire-retardant lumber, plywood, etc.	Asbestos Metal sheets
Poles	Metal tubing Precast concrete

G. Environmental Impact Potential

1. Hazards to humans:* Creosote vapors cause eye and nose irritation. Liquid creosote is a primary skin irritant, but is not an eye irritant. The irritation thresholds for eyes, nose and throat have not been determined. Photosensitization has been reported. Fair skin men are reportedly sensitive to creosote (vapors or liquid not specified) while dark skin workers show remarkable resistance.

Cutaneous carcinomas are reported to involve hands, forearms, scrotum, face, neck and penis. Available information on such cases indicates gross contact of skin and clothing, minimal protective measures and minimal personal hygiene.

An authoritative text[82/] makes the following statement concerning the hazards of creosote to humans.

"Workmen sometimes object to handling the treated wood, as the preservative soils their clothes and in some cases may burn the skin of the face and hands, causing injury similar to sunburn. Creosoted timber has no other apparent effects on the health of people working with or near it, nor is it in any way injurious to the occupants of buildings in which such treated material has been used. With regard to the health factor, it may be pointed out that creosoted wood-stave pipe is successfully used in some localities for conducting drinking water to cities."[74/]

2. Mammalian toxicity: Recent studies[83/] of mammalian toxicity of creosote are summarized below.

a. Based on mortality during a 14-day post-exposure period, the single oral dose LD_{50} was estimated to be 1.7 gm/kg body weight (albino rats). Creosote is, therefore, classified as a toxic substance, but the magnitude of this toxicity is low. This LD_{50} would be approximately equivalent to a 4 oz dose for a 150-lb man. Furthermore the oral LD_{50} of sodium chloride for rats is 3.0 gm/kg, so that creosote is roughly about twice as toxic as table salt.

b. The single dose skin penetration LD_{50} of creosote on albino rabbits is greater than 7.95 gm/kg body weight. Thus, creosote is defined as being a relatively low toxic substance for the skin penetration test.

c. Creosote was put into the eyes of male albino rabbits, and it was judged not to be classified as an eye irritant.

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* Source: Koppers Company, personal communication, 1973.

d. Creosote was placed on the abraded skin areas of male albino rabbits for a maximum period of 24 hr. Severe epidermal flaking occurred; thus, the material is defined as a primary skin irritant.

e. Near-saturated vapors of creosote were provided for the inhalation exporure to a group of albino rats. The results indicated that creosote is believed to have a low order of toxicity. It does not fall within the "toxic" or "highly toxic" substances definition.

Some references to the possible carcinogenic nature of creosote have been reported in the literature. A study with mice indicated that skin cancers were recognized as being caused by creosote, and lung cancer was suspected to be.[84] Another study concluded, however, that "the basic fraction of creosote oil was found to be noncarcinogenic for mouse skin."[85]

Another study was recently conducted by NIOSH on the effect of coal tar pitch volatiles on four species of rats, hamsters, rabbits and two species of mice. The coal tar was atomized into an air stream and into cages at 0.2, 2.0, 10.0 and 20.0 mg/m^3. The animals were continuously exposed, 24 hr/day for 90 days. Post observations were then made for 15 months. Only mice at the 10 and 20 mg level showed signs of skin effects. These two higher exposure levels are massive--something like a shower. On sacrificing the rats, no instances were found of lung, bladder or kidney tumors.[86]

3. Hazards to the environment: The limited data available at the present time indicate that the hazards of creosote to the environment are minimal.

There is a major difference between the use of creosote and most other pesticides; creosote is not sprayed or widely distributed for the purpose of killing pests over a wide area; creosote is impregnated into wood, and there are strong indications that it remains within the wood over long periods of time. For example, a 1972 study[87] determined that, during a 40-year period, the retention of creosote in Douglas fir marine piling did not change significantly. Another study[88] reported, in 1964, that the loss of polycyclic aromatic compounds from creosote-treated utility poles is not a significant form of air pollution; the pine forests contribute far more pollutants in the form of hydrocarbons than do creosote wood products.

A very recent paper has explored the environmental hazards of creosote in greater detail. Acute toxicity data have been determined for certain birds and fish, and these data are reproduced in Table XXXVIII. The data inspired the following comment concerning the hazard of creosote to the environment:

"If creosote, after being used for over 100 years, was such an extremely hazardous material, there would be recorded somewhere many instances of its detrimental effects on domestic animals, humans and wildlife. But these harmful effects have not occurred. In fact, as shown by the bird and fish data, creosote is low to moderate in toxicity."[89]

TABLE XXXVIII

ACUTE TOXICITY DATA FOR AVIAN SPECIES AND FISH SPECIES FOR CREOSOTE-COAL TAR SOLUTION (60/40) AND SEVERAL INSECTICIDES[89]

Species	8-Day Dietary LD_{50} (ppm)	Preservative and Insecticide Compounds
Bobwhite quail	1,261	Creosote-coal tar (60/40)
	38	Dieldrin
Mallard duck	10,388	Creosote-coal tar (60/40)
	164	Dieldrin

Species	Static Fish Bioassay-96 Hr Nominal Water Concentration TL_{50} (ppb)	Preservative and Insecticide Compounds
Bluegills	990	Creosote-coal tar (60/40)
	8	DDT
	103	Malathion
Rainbow Trout	880	Creosote-coal tar (60/40)
	7	DDT
	170	Malathion

CASE STUDY NO. 21. MANEB

A. Product Description

Chemical Name: Manganese Ethylenebisdithiocarbamate

Trade Names: Chloroble M, Dithane M-22, Dithane M-22 Special, Kypman 80, Maneba, Manebgan, Manesan, Manzate, Manzate D, Sopranebe, Trimangol, Vancide, Maneb 80

Pesticide Class: Fungicide

Properties: Yellow crystals, decomposes on heating; Sparingly soluble in water; insoluble in most organic solvents

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972[a] Production
Rohm and Haas Company	Philadelphia, Pennsylvania	20-25 million lb (Estimated total dithiocarbamates)	7 million lb
E. I. duPont de Nemours and Company, Inc.	La Porte, Texas	15-20 million lb (Estimated total dithiocarbamates)	5 million lb

[a] Maneb and maneb plus zinc salt, but excluding mancozeb (see text).

Maneb production is unusually difficult to estimate and a few comments are needed to explain the basis of our estimates. Maneb was introduced in 1950 by Du Pont under the name Manzate® and was soon produced (under license) by Rohm and Haas under the name Dithane M-22. Maneb was produced by mixing at high concentrations a water-soluble manganese salt with a soluble ethylenebisdithiocarbamate salt, recovering the insoluble product* and then drying it. The original maneb had relatively poor shelf life and both companies developed products that contained a zinc salt

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* At low concentrations of reactants a soluble form of maneb is obtained which is believed to be a cyclic, monomeric molecular form, compared to a linear, polymeric from for the insoluble maneb.

(apparently the sulfate) as a stabilizer, i.e., Manzate D and Dithane M-22 Special. Both maneb and maneb with the zinc salt were marketed primarily as 80% wettable powder stated to contain 16.5% manganese, i.e., the zinc was included with the 20% inert ingredient. Maneb is, in fact, generally formulated with a higher content of AI (e.g., 87%) to allow for instability losses in storage.

In 1961 Rohm and Haas introduced an improved product which they described as a complex metal salt--a coordination compound--of maneb. Made by mixing an aqueous slurry of maneb and a soluble zinc salt and then drying the mixture, this product was marketed by Rohm and Haas under the trade name Dithane M-45 and then (under license) by DuPont under the name Manzate 200. Subsequently, very similar if not identical products were marketed in Europe, Canada and elsewhere under the common name "mancozeb." Rohm and Haas had obtained approval of the use of this common name for the active ingredient in Dithane M-45 from the ISO (International Organization for Standards), but has never received approval for its use in the U.S.

Some confusion exists over the nature of mancozeb. Dithane M-45 and Manzate 200 are marketed as 80% WP stated to contain 16% manganese and 2% zinc. By difference, the ethylenebisdithiocarbamate (EDC) would therefore make up about 62% of the product and the atomic ratio would be $Mn_{1.00}$, $An_{0.10}$, $EDC_{1.01}$. Martin's Pesticide Manual reports a somewhat different composition for mancozeb, i.e., 20% Mn, 2.5% Zn. In either case, the zinc is not present in the stoichiometric amount normally present in a coordination compound. The structure has been postulated to be a linear polymer form of maneb in which about 6% of the units contain zinc, but Melnikov's Chemistry of Pesticides simply calls mancozeb a mixture of maneb and zineb*, which is apparently inconsistent with U.S. practice.

At any rate, products of the mancozeb type (i.e., Dithane M-45, etc.) have improved stability compared to the older maneb formulations, while providing essentially the same fungal control. They are growing in importance, replacing much of the previous uses of maneb and zineb, and may by now (1974) be the most widely used member of the dithiocarbamate family, worldwide, according to an industry source. The U.S. production of the mancozeb type product is, however, difficult to estimate; the Tariff Commission does not even list it as a product, although both maneb and zineb are listed.

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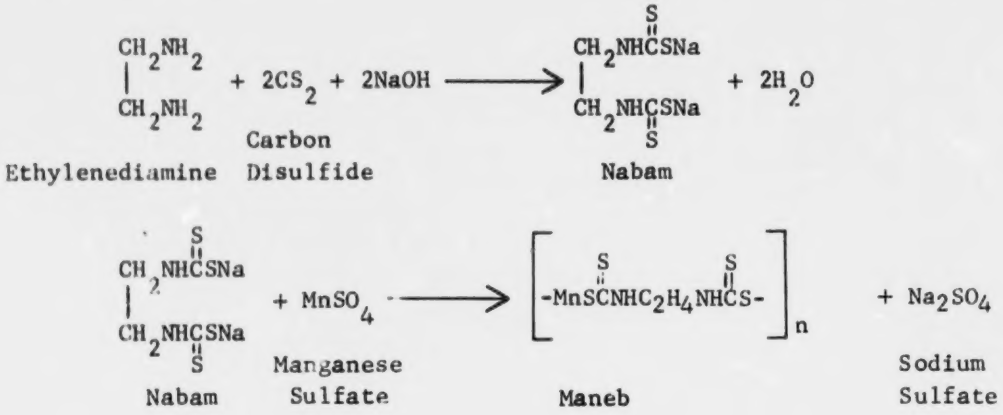
* Zinc ethylenebisdithiocarbamate.

C. Production Methods and Waste Control Technology

The reaction chemistry for maneb production is believed to be approximately as shown below; based on discussions with the manufacturers.



$$\begin{array}{l}CH_2NH_2\\ |\\ CH_2NH_2\end{array} + 2CS_2 + 2NaOH \longrightarrow \begin{array}{l}CH_2NH\overset{S}{\overset{\|}{C}}SNa\\ |\\ CH_2NH\underset{S}{\underset{\|}{C}}SNa\end{array} + 2H_2O$$

$$\begin{array}{l}CH_2NH\overset{S}{\overset{\|}{C}}SNa\\ |\\ CH_2NH\underset{S}{\underset{\|}{C}}SNa\end{array} + MnSO_4 \longrightarrow \left[-MnS\overset{S}{\overset{\|}{C}}NHC_2H_4NH\overset{S}{\overset{\|}{C}}S-\right]_n + Na_2SO_4$$

A production and waste control schematic for maneb is shown in Figure 50.

Rohm and Haas produces maneb in Northeast Philadelphia. Raw materials include carbon disulfide, ethylenediamine and sodium hydroxide (50%). These are reacted in stainless-steel, cooled units. The exothermic reaction is controlled by the feed rate and excess carbon disulfide is distilled out. The sodium hydroxide addition controls pH. The resulting concentrated nabam solution is reacted (within 24 hr) with manganese sulfate, and the desired manganese ethylenebisdithiocarbamate is precipitated. The slurry is washed with water to remove sodium sulfate and dried to less than 1% water content. Process by-products include sodium sulfate and small amounts of carbon disulfide and sodium hydroxide.

Origin of the process raw materials is as follows: manganese sulfate is a by-product of the manufacture of hydroquinone. It is received in powder form by hopper cars from Kingsport, Tennessee, or as a liquid solution from Kingsport or Baltimore, Maryland. The manganese sulfate is conveyed from the hopper car by means of an air system (micropulsator). The hopper car unloading area must be well ventilated, and the evacuated air is passed through dust collectors. Ethylene diamine is received by tank car from Texas City or Freeport, Texas. Carbon disulfide is received by tank car from Delaware City, or from Natrium or South Charleston, West Virginia. Sodium hydroxide is received by rail from Freeport, Texas; Natrium, West Virginia; or Baltimore, Maryland.

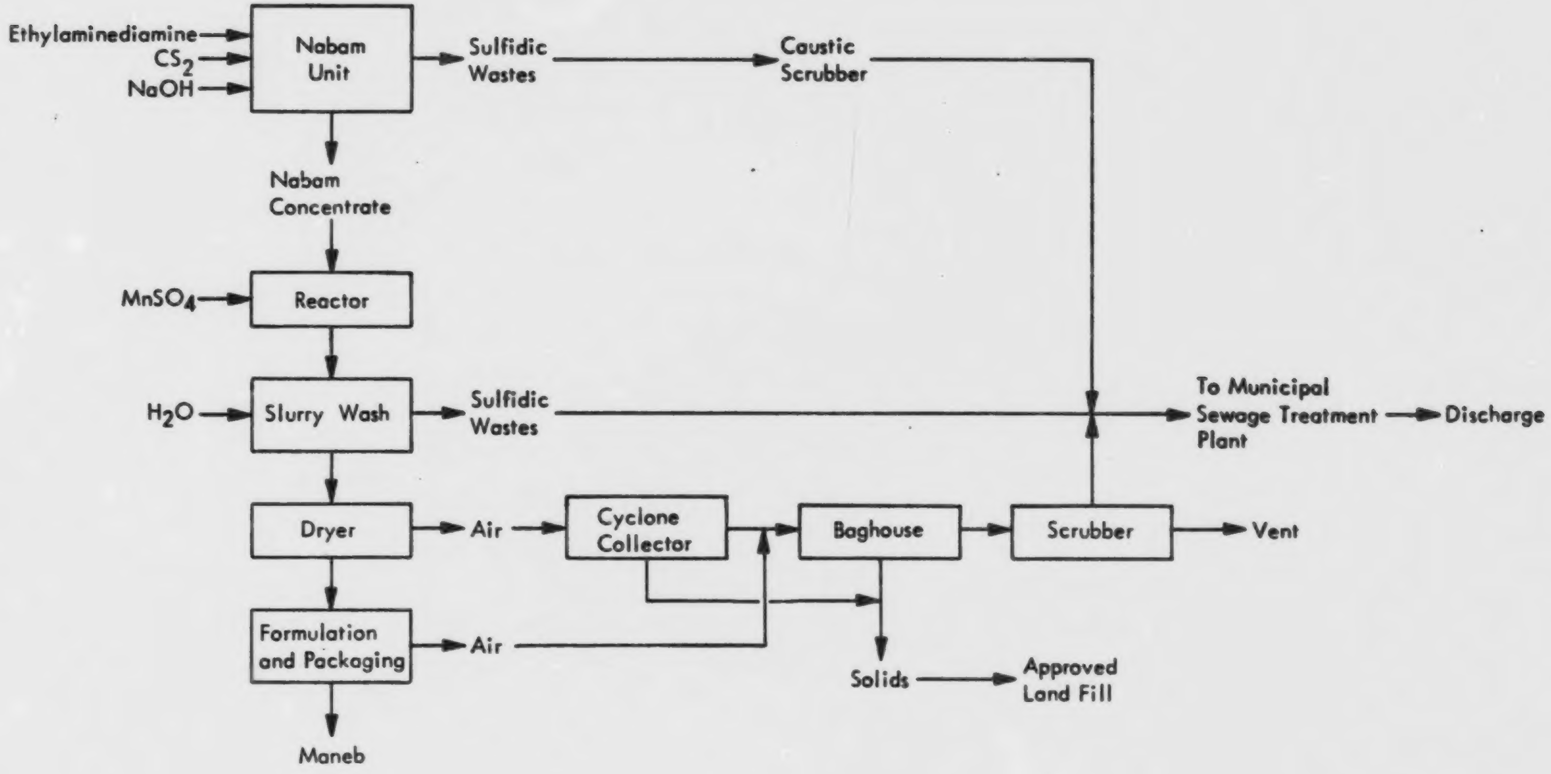

Ethylaminediamine
CS_2
NaOH
Nabam Unit
Sulfidic Wastes
Caustic Scrubber
Nabam Concentrate
$MnSO_4$
Reactor
H_2O
Slurry Wash
Sulfidic Wastes
To Municipal Sewage Treatment Plant
Discharge
Dryer
Air
Cyclone Collector
Baghouse
Scrubber
Vent
Formulation and Packaging
Air
Solids
Approved Land Fill
Maneb

Figure 50 - Production and Waste Schematic for Maneb

Pollution abatement problems and procedures are as follows. Air emissions are controlled by cyclone collectors, bag filters, and scrubbers. A small amount of hydrogen sulfide is given off in the reaction; this is collected from process vents and passed through caustic (5%) scrubbers before release to the atmosphere. Emissions from the drying step are also controlled. A cyclone collector, bag filter and scrubber are used to remove particulates from the air. The final packaging operation is dusty; this area must be well ventilated and the airstream is passed through bag filters before release. About 2% of the total weight of product is lost as solids. Solid wastes (broken bags, sweepings, solids collected in the dust collectors, etc.) are discharged at an approved dump site in a Philadelphia suburb (outside the city limits) or on the New Jersey side. None of the solid waste, including spillage from broken bags, is recovered.

The liquid waste stream contains primarily salts, about 9 lb per 13 lb of Maneb produced. The salts are mostly sodium sulfate, with some manganese sulfate and certain by-products, such as sodium trithiocarbamate, formed by the reaction of carbon disulfide with sodium hydroxide. The liquid stream goes untreated to a large city sewage treatment plant. Rohm and Haas (and other chemical plants in the vicinity) have an agreement with the city under which they can discharge their effluent to this plant for treatment. Thus, the Rohm and Haas plant does not have separate waste treatment facilities and does not require any discharge permits other than agreement from the city to accept their waste streams. The waste stream going to the city treatment plant must contain less than 1% solids. Non-contaminated cooling water is monitored and discharged directly to the river.

Waste treatment methods employed by Rohm and Haas in the maneb process do not include incineration (sulfur dioxide and manganese would create air pollution problems), evaporation, deep-well disposal (The salts would tend to clog the deep well) or sea dumping.

Maneb is also manufactured by Du Pont at the LaPorte, Texas, plant. Raw materials come primarily from near-by sources by tank car. Du Pont did not provide any information on the nature of the process. Processing wastes go to waste treatment systems which are common to all units at the LaPorte site. These systems include deep-well disposal, incineration, flares, two biological treatment systems, and barging to sea.

D. Formulation, Packaging, and Distribution

Rohm and Haas markets maneb with a declared formulation of 80% AI, but which usually has 87% AI initially to compensate for AI lost during storage. Dispersing agents, nongreasing agents, stabilizers and other adjuvants are added to the technical product. Maneb has a shelf life of 2 years if packaged in foil, waterproofed containers.

Packaging is in 1 kg or 3-, 4-1/2, 20-, or 50-lb bags or in 50, 55, or 250 lb fiber pack drums. The bags and drums are shipped by truck, rail, or containerized. There are no bulk shipments. Exports, which have to compete against many sources of overseas production, leave the U.S. at New York, Philadelphia, Baltimore or from West Coast ports.

The geographic use pattern for all carbamate fungicides was estimated by Rohm and Haas as follows: Eastern U.S., 30%; Southeast, 21%; Midweat, 28%; South, 8%; and West, 13%.

DuPont also formulates its technical AI into an 80% WP. Zinc is added to some formulations such as Manzate D and Manzate 200. The maneb wettable powder is packaged in fiber drums or paper bags. These are shipped by rail or by truck.

E. Use Patterns

General : Maneb is a leading product in a group of dithiocarbamate compounds whose fungicidal efficacy was discovered and has been commercially exploited since the 1930's. Several U.S. and European chemical companies have been active in this field. The market shares of the present-day dithiocarbamate fungicides (primarily metal salts of ethylene bisdithiocarbamates) reflect not only the inherent fungicidal potentials of the chemicals, but also the extent of development and marketing efforts by the chemical companies involved, as influenced by their respective patent positions. Maneb is rather unstable. Zinc is added to many maneb formulations to increase stability. Maneb is a relatively inexpensive fungicide.

Action : Contact fungicide, broad spectrum. Protective (not curative) action. No systemic activity. Mechanism of action not fully understood.

Target Crops : Potatoes, tomatoes, other vegetable crops; apples and other fruit and nut crops; turf grasses, especially Merion bluegrass; wheat and other small grains (seed treatment).

Target Diseases : Late blight; early blight; anthracnose; *Septoria* leaf spot; gray leaf spot; scab; cedar apple rust; downy mildew; bunt; damping-off; *Helminthosporium*, other fungus diseases.

Application : Foliar spray (or dust) treatments, mostly by ground equipment. Seed treatment.

Rates of Application : 1-2.4 lb AI/acre; up to 5 lb AI/acre for some uses. 1.2-1.6 lb AI/100 gal., 2 oz AI/bushel for seed treatment.

Frequency : 3-8, up to 15 foliar applications per growing season. Seed treatments: once per season.

Time of Application : Seed treatments prior to planting; foliar treatments throughout the growing season.

Estimated Distribution : (All figures in millions of pounds AI per year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
12.0	0.1	4.5	7.6

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

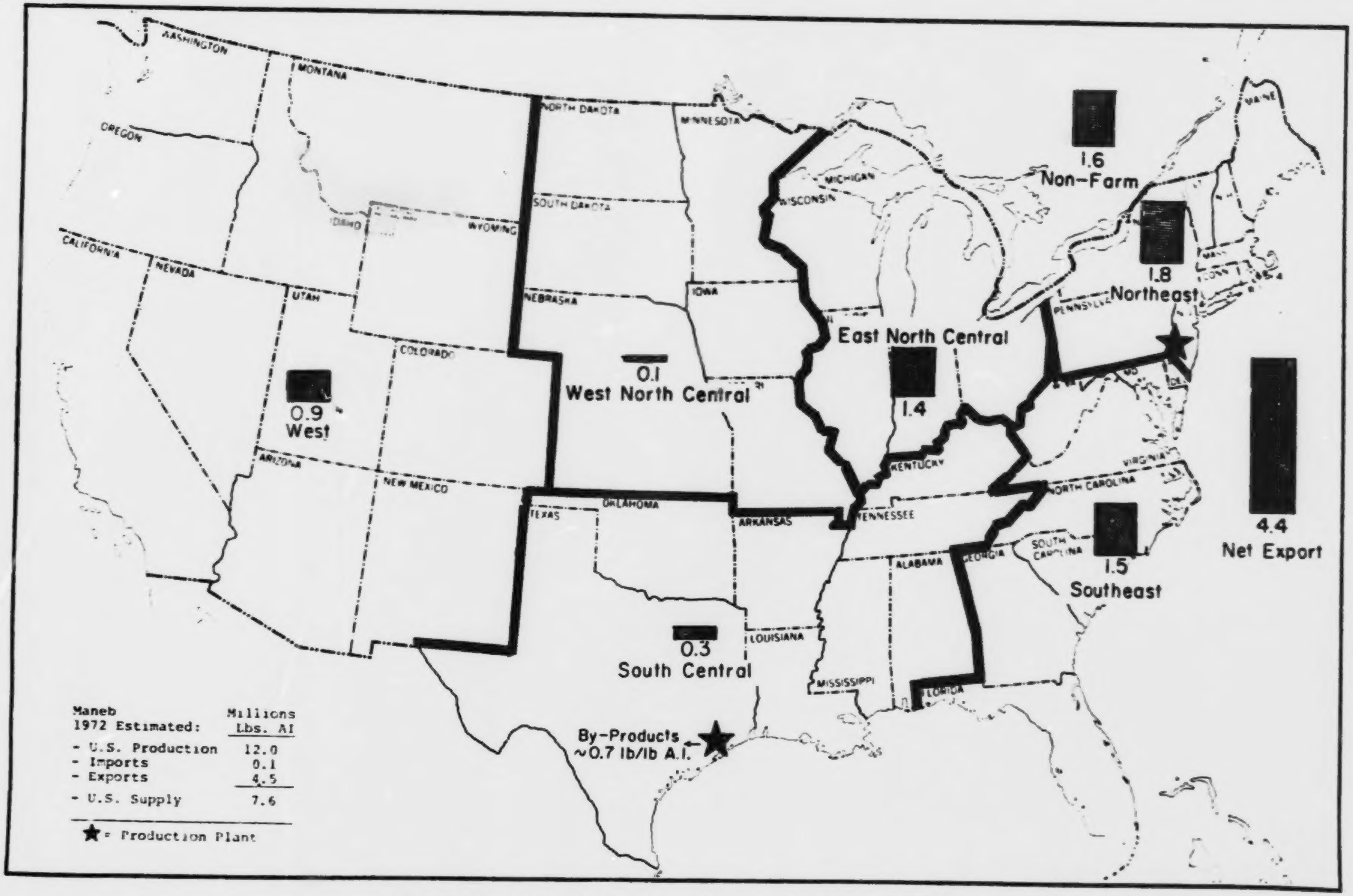
Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	1.8	Negl.	Negl.		
SE	1.5				
NC	1.5				
SC	0.3				
W	0.9				
Totals	6.0	Negl.	Negl.	1.6	7.6

A Materials flow diagram for maneb is shown in Figure 51.

F. Alternatives

Chemicals : Other dithiocarbamate fungicides (including zineb, mancozeb; metiram, and others); other organic and some inorganic fungicides.

Nonchemical : There are no specific, practical, nonchemical alternatives for control of the plant diseases controlled by these fungicides.



WASHINGTON
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
MINNESOTA
IOWA
WISCONSIN
MICHIGAN
TEXAS
OKLAHOMA
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
PENNSYLVANIA
MAINE
MASS
CONN
DEL
0.9
West
0.1
West North Central
0.3
South Central
By-Products
~0.7 lb/lb A.I.
1.4
East North Central
1.6
Non-Farm
1.8
Northeast
1.5
Southeast
4.4
Net Export

Maneb 1972 Estimated:	Millions Lbs. AI
- U.S. Production	12.0
- Imports	0.1
- Exports	4.5
- U.S. Supply	7.6

★ = Production Plant

Figure 51 - Materials Flow Diagram for Maneb, 1972

G. Environmental Impact Potential

Mammalian Toxicity : The oral acute LD_{50} of maneb to rats is over 5,000 mg/kg, placing it into the "relatively nontoxic" category by this criterion. No data are available on the acute dermal or inhalation toxicity of maneb. Maneb may cause slight to moderate irritation of eyes, nose, throat, and skin. The signal word "caution" is required for labels of the 80% wettable powder formulations, the most commonly used commercial form of maneb.

In chronic toxicity studies, the no-effect level was 250 ppm in the diet of rats in a 2-year study, 80 ppm in the diet of dogs in a 1-year study. Tolerances for residues of maneb have been established for many crops, ranging from 0.1-45.0 ppm. 4.0-10.0 ppm for most crops.

Ethylene thiourea (ETU) is a metabolite of maneb and occurs in varying amounts as an impurity in formulated products. This chemical is considered a "secondary carcinogen." It stimulates the pituitary to produce thyroid stimulating hormone that may cause thyroid hyperplasia which may turn malignant. In 2-year chronic feeding studies with maneb, thyroid hyperplasia was the predominant adverse sympton. Its severity was clearly dose related. There appears to be a no-effect level below which ETU does not result in thyroid hyperplasia.

Nontarget Organisms : Maneb is moderately toxic to fishes, relatively nontoxic to birds and wild mammals. No data are available on its toxicity to lower aquatic organisms of soil organisms, or on its possible buildup in food chains. In view of its instability, the latter is not likely to occur.

Environment : Maneb is quite instable. No experimental data are available on the routes and rates of its degradation in the environment after application. It is not persistent on treated plants or in the soil. Maneb does not volatilize from treated surfaces to any significant extent. It may leach from soils, but it is primarily applied to plant foliage and is not likely to penetrate into soil profiles in large enough quantities for leaching to become a problem. Its physical and chemical properties make it very unlikely that significant quantities of maneb could pollute the environment away from target areas. In treated areas, degradation appears to occur rapidly.

Evaluation : Maneb irritates mucuous membranes. The question of possible adverse health effects from ethylene thiourea (ETU), a metabolite of maneb, is not finally resolved at this time. Maneb decomposition in storage may result in the generation of flammable vapors. Aside from these provisos, there are no indications of serious hazards to human health or to terrestrial ecosystems outside of target areas from the use of maneb as a fungicide.

Maneb is toxic to fish. Its toxicity to lower aquatic organisms is not known. However, it is unlikely that maneb residues will get into waterways in sufficient concentrations to harm aquatic organisms, except through gross negligence or misuse.

CASE STUDY NO. 22. PENTACHLOROPHENOL

A. Product Description

Chemical Name: Pentachlorophenol (also called penta and PCP)

Trade Names: Dowicide 7, Santophen, Pentachlorol, Sinituho, Weedone (Dowicide G and Santobrite are names of sodium pentachlorophenate.)

Pesticide Class: Wood preservative, contact herbicide, molluscicide

Properties: Buff color crystals; melting point > 178°C (technical), 191°C (anhydrous). Soluble in ethanol and methanol, slightly soluble in aliphatic hydrocarbon solvents.

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Dow Chem. U.S.A	Midland, Mich.	18 million lb	12 million lb
Monsanto Co. Monsanto Indust. Chems. Co.	Sauget, Ill.	26 million lb	18 million lb
Reichhold Chems., Inc.	Tacoma, Wash.	12 million lb	8 million lb
Vulcan Materials Co. Chems. Div.	Wichita, Kans.	14 million lb	12 million lb
	Total	70 million lb	50 million lb

The production figures include the production of the sodium salt of PCP. Dow was the major producer of the sodium salt in 1972 and Monsanto apparently bought its sodium salt from Dow. Reichhold produces the salt also, but Vulcan does not. The total 1972 production figure is based on Tariff Commission data, but industry sources estimate total production as high as 56 million pounds.

C. Production Methods and Waste Treatment Technology

The production of pentachlorophenol by the chlorination of phenol* has been described in considerable detail.90/ The reaction chemistry is shown below, and a production and waste schematic is shown in Figure 52.

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* Industry sources agree that PCP was never produced in the U.S. by the hydrolysis of hexachlorobenzene.

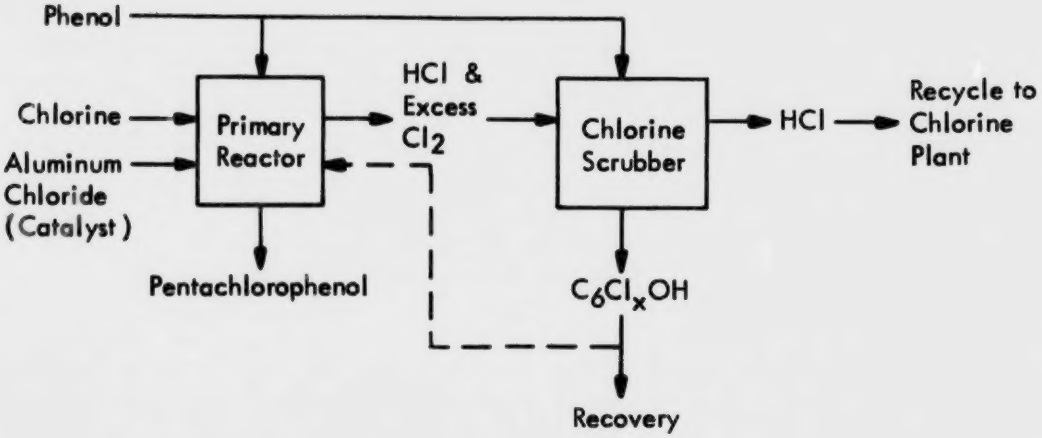
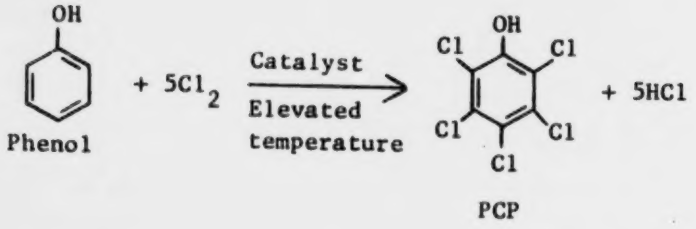

Phenol
Chlorine
Aluminum Chloride (Catalyst)
Primary Reactor
HCl & Excess Cl2
Chlorine Scrubber
HCl
Recycle to Chlorine Plant
Pentachlorophenol
C6ClxOH
Recovery

Figure 52 - Production and Waste Schematic for Pentachlorophenol



Some general comments[90] on the process follow.

The chlorination is performed at substantially atmospheric pressure. The temperature of the phenol in the primary reactor at the start is in the range of 65-130°C (preferably 105°C) and is held in this range until the melting point of the product reaches 95°C. About three to four atoms of chlorine are combined at this point, and the temperature is progressively increased to maintain a temperature of about 10°C over the product melting point, until the reaction is completed in 5-15 hr. The mixture is a liquid, and a solvent is not required, but the catalyst concentration is critical; about 0.0075 mol of anhydrous aluminum chloride is usually used per mol of phenol.

The off-gas from the chlorination reactor (largely HCl during the initial reaction and chlorine near the conclusion) is sent to a scrubber-reactor system containing excess phenol. It is held at a temperature such that the chlorine is almost completely reacted to give the lower chlorinated phenols, which may be either separated, purified and sold, or returned to be used as the primary pentachlorophenol reactor. The residual gas is substantially pure HCl.

Dow produces PCP at Midland only. They make phenol from benzene (via monochlorobenzene), but this method of making phenol is being generally replaced by the cumene oxidation process. Monsanto also makes both the phenol and chlorine, while Vulcan makes the chlorine, but purchases the phenol, and Reichold makes the phenol, but purchases the chlorine.

Dow makes PCP with dedicated equipment, and recycles the HCl in the process. The PCP contains about 10% tetrachlorophenol, but Dow claims no hexachlorobenzene is formed in their process.

Monsanto's PCP also contains about 10% tetrachlorophenol. Monsanto generates its own chlorine and produces phenol in its Gulf Coast plant. The by-product HCl is recovered as muriatic acid. Monsanto also has no problem with formation of hexachlorobenzene.

The commercial products are contaminated with various amounts of other chlorinated phenols and chlorinated dioxins. Dow has recently commercialized a product manufactured to minimize the dioxin content; it has the following composition:

Pentachlorophenol	88%
2,3,4,6-Tetrachlorophenol	12%
Chlorinated dioxins	
Octachlorodibenzo-p-dioxin	30 ppm, max.
Hexachlorodibenzo-p-dioxins	1 ppm, max.

However, some commercial products have contained up to 2,500 ppm of the octachlorodioxin and up to 27 ppm of the hexachlorodioxins. (The effects of these contaminants on toxicity are discussed in a subsequent portion of this case study.

D. Formulation and Distribution

Pentachlorophenol is available as a formulated product to be applied with a hydrocarbon diluent or as an emulsifiable solution.

Solution concentrates are designed for use in formulating ready-to-use products by manufacturers; and for use by large consumers. PCP is usually applied to wood products after dilution to a 5% solution with solvents such as mineral spirits, No. 2 fuel oil or kerosene. Liquid petroleum gas (LPG) and methylene chloride are also sometimes used as solvents. The energy crisis may cut into the availability of diluent oils.

Dow does not formulate any PCP products, but ships to buyers for formulation. The PCP in prilled form is shipped in fiber drums, 100-lb bags and 2,000-lb containers. Most shipments are made by truck, but some shipments are made in sealed hopper cars leased from the railroad. (Dow representatives were not sure who cleaned the cars.)

PCP is sold by Monsanto in 50-lb bags, by bulk (in prill form), and in 1/2 or 1-ton blocks with a metal hook cast in the center (the blocks are used to make batches of oil-PCP, since it is not sold as a solution). The sodium salt is sold in 50-lb bags and 200-lb fiber-pack drums, both of which are nonreturnable and combustible.

Bags and solid blocks are shipped from Monsanto in trucks and freight cars. Bulk shipments from Monsanto are by hopper truck and hopper cars. It is the responsibility of the railroad or trucking company to deliver a clean car; the cleaning procedure utilized was unknown to Monsanto.

Most of the PCP sold by Vulcan Materials Company is 96-97% prill or flake material. About half of this is shipped to wood preservation plants in special 20-ton bulk trailer containers that can be unloaded by air pressure (self-contained pressure source).

Reichhold also manufactures PCP in prilled form and packages the product in 50-lb bags. They also ship bulk prills. Reichhold also produces 1/2- and 1-ton blocks.

E. Use Patterns

Most of the pentachlorophenol produced in the U.S. is used for the preservation of wood; about 38 million lb, or 78% of total production, goes directly to wood preservation plants.

About 17% (about 8.5 million lb) of the total amount of PCP produced is converted to the sodium salt.

Pentachlorophenol was formerly widely used as a herbicide, although frequently in combination with other herbicides such as 2,4-D, bromacil, or one of the triazines. This usage has apparently decreased substantially in recent years and current herbicide use is probably down to 1 million lb/year from a recent high of 18 million lb/year. About 1.5 million lb of PCP is used in home and garden applications.

These consumption patterns for pentachlorophenol are summarized in Table XXXIX, and the various uses are discussed below.

Wood preservation: The major use for pentachlorophenol is in the preservation of wood. The wood preservation industry was described briefly in Chapter IV of this report, and in Case Study No. 20 on creosote. Wood is treated with PCP mostly by using a pressure application method. (For details, see the case study on creosote.) Utility poles, the major PCP-treated wood product, are treated with PCP (rather than creosote) to keep their appearance pleasing. About 0.5 lb of PCP is required for each cubic foot of wood preserved.

Table XL presents MRI estimates of the amounts of PCP used at wood preservation plants in various regions of the U.S.

We have made additional estimates of the geographical use distribution of PCP used in wood preservation. These estimates are based on the fact that 97% of the PCP used in wood preservation is used for: (a) utility poles and crossarms (62%); and (b) lumber, timber, and fence posts (35%). (See Table X in the section of this report dealing with the wood preservation industry.) We have assumed that the use of these materials is proportional to the population of each region. The resulting estimates of the ultimate location of PCP-treated wood are also presented in Table XL.

TABLE XXXIX

U.S. CONSUMPTION OF PENTACHLOROPHENOL[a]

Application	Quantity Consumed (millions of lb/year)	Percent
Wood Preservation, Commercial	38	78
Sodium Salt (many uses, see text)	6	12
Plywood and Fiberboard Waterproofing	3	6
Home and Garden Applications (mostly termite treatment)	1.5	3
Herbicide	0.5	1
TOTAL	49.0	100

---

[a] Source: MRI Estimates.

TABLE XL

INDUSTRIAL/COMMERCIAL USE DISTRIBUTION FOR PENTACHLOROPHENOL[a]

(All figures in millions of lb AI/year, 1972)

Region	PCP Used by Wood Preservation Plants	Ultimate Location of PCP-Treated Wood
NE	0.4	9
NC	3.6	11
SE	11.0	6
SC	14.0	6
W	9.0	6
TOTAL	38.0	38.0

---

[a] Source: MRI Estimates.

Waste treatment technology in wood preservation with pentachlorophenol: Some of the general procedures and some of the major waste treatment problems encountered in the preservation of wood were described in the Case Study No. 20 on creosote.

Wood preservation procedures are similar whether the wood is being treated with pentachlorophenol or creosote and, thus, the problems generally are of the same kind.

In a recent report,[91/] the characteristics of a typical wastewater were presented:

TABLE XLI

TYPICAL CHARACTERISTICS OF WASTEWATER FROM A WOOD PRESERVATION PLANT USING PENTACHLOROPHENOL

Constituent	Concentration (mg/ℓ)
Total solids	640
Suspended solids	180
COD	1,300
Reducing sugars	68
Chlorophenols (penta and tetra)	23

In a "fairly strong" wastewater. the concentration of pentachlorophenol can be as high as 100 mg/liter.[91/] Pentachlorophenol is very difficult to degrade by biological treatment.[91/]

Sodium salt of pentachlorophenol: The sodium salt of pentachlorophenol has literally hundreds of uses; it is widely used geographically. It is a wide-spectrum fungicide and bactericide. About one-third of the sodium salt is used for the treatment of sap stain (a fungicidal growth which causes discoloration) in freshly sawed logs and unseasoned wood. One-third is used in the production of pressed board and insulation board, and the remaining one-third is used to inhibit algae and fungi in air-conditioning cooling towers. In this application, the water must be "slug-treated" periodically, because about 75% of the PCP degrades in water in 24 hr; continuous treatment would be prohibitively expensive.

Estimated Distribution : (All figures in millions of lb AI/year, 1972)

U.S. Production	Imports	Exports	Domestic Consumption
49.7	0	0.7	49.0

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE		11.0			
SE		7.5			
NC		13.5			
SC		7.5			
W		8.0			
Totals	Negl.	47.5	Negl.	1.5	49.0

A materials flow diagram for pentachlorophenol is shown in Figure 53.

F. Alternatives

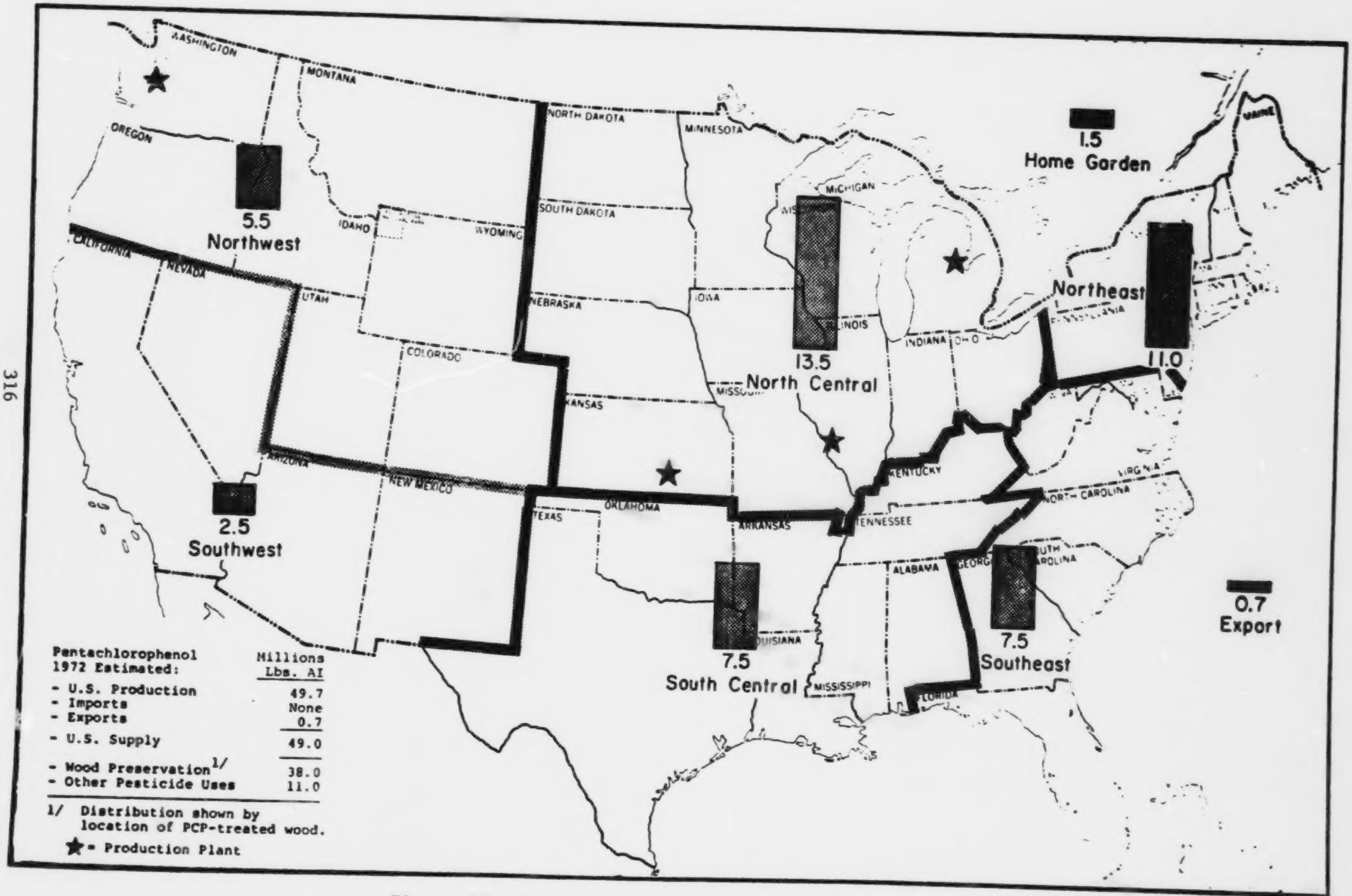
A discussion of the alternatives to pentachlorophenol in the preservation of wood is presented in the case study for creosote.

G. Environmental Impact Potential

1. Hazards to humans

a. Eyes: Pentachlorophenol is capable of causing conjunctival redness, iritis, and slight corneal injury. Prompt flushing of contaminated eyes will lessen the degree of injury.

b. Skin: A single, prolonged skin contact with the product may cause slight redness and swelling. Repeated prolonged contact may result in a chemical burn. PCP is not absorbed through the skin in acutely toxic amounts. However, the product, in solution, may be absorbed through the skin in acutely toxic amounts depending upon the solvent and the concentration.


WASHINGTON
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
MICHIGAN
WIS
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
MAINE
5.5
Northwest
2.5
Southwest
13.5
North Central
7.5
South Central
7.5
Southeast
11.0
Northeast
1.5
Home Garden
0.7
Export

Pentachlorophenol 1972 Estimated:	Millions Lbs. AI
- U.S. Production	49.7
- Imports	None
- Exports	0.7
- U.S. Supply	49.0
- Wood Preservation 1/	38.0
- Other Pesticide Uses	11.0

1/ Distribution shown by location of PCP-treated wood.

★ = Production Plant

Figure 53 - Materials Flow Diagram for Pentachlorophenol

c. Inhalation: Dusts are very irritating to upper respiratory tract and eyes.

2. Mammalian toxicity:

a. Acute toxicity:

LD_{50} values (oral): Guinea pigs - 50-140 mg/kg
Rats - 27-80 mg/kg

Minimum lethal dose (LD_{100}): Rabbits - 70-130 mg/kg

b. Subacute toxicity:

Rats - 18-20 days - 5% solution by intubation: 100 mg/kg - slight liver and kidney injury.

Rabbits - 15 days - same method as rats: 35 mg/kg - gradual weight loss due to poor food intake.

c. Chronic toxicity:

Rats - 26 weeks: 5 mg/day - no ill effects other than poor weight gain due to reduced food intake. PCP is rapidly eliminated from the body, primarily in the urine.

3. Hazards to the environment:

a. General toxicity to wildlife and fish: Mortality of goldfish after 24 hr exposure - 0% at 0.1 ppm; 100% at 0.4 ppm.

b. Adsorption and leaching characteristics in basic soil types: Leaches readily--some evidence of partial adsorption in certain organic and clay soils.

c. Microbial breakdown: There is no build-up in soil, and microbial breakdown is assumed.

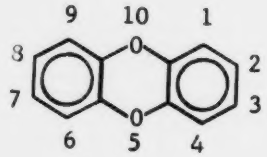
d. Resultant average persistence at recommended herbicidal application rates: Two to four weeks.

4. Pentachlorophenol in water: Pentachlorophenol has been found in streams and has accumulated in fish tissues following industrial discharge.92,93,94/ Concentrations of PCP in sewage influent from three Oregon cities ranged between 1 and 5 ppb; the subsequent sewage treatment (biological treatment, trickling filter) was shown to decrease the concentration by

only 4-28%. Conventional water processing was shown to remove about 60% of the pentachlorophenol, leaving 40% in the finished drinking water.

5. The dioxin question: The presence of certain compounds called "chlorinated dibenzo dioxins" in commercial pentachlorophenol has recently caused much concern for the safety of this product to man and the environment. The concern originates mainly because of the fact that some chlorinated dioxin compounds are very highly toxic.

The structure and numbering system for substituted dioxins is shown below:



The 2,3,7,8-tetrachlorodibenzo-p-dioxin produces very severe toxicological responses; the LD_{50} ranges from 0.6 micrograms per kilogram (µg/kg) in male guinea pigs to 115 µg/kg in rabbits; as little as 0.04 µg/ml produces chloracne in rabbit ear bioassays. However, this dioxin isomer is not present in any commercial pentachlorophenol product.

The dioxins present in commercial pentachlorophenol are hexachloro- and octachlorodibenzo-p-dioxins.

Hexachlorodibenzo-p-dioxins are fatal to rats at doses of 100 mg/kg. Chloroform solutions containing 10-50 µl/ml show acnegenic activity. A dose of 100 µg/kg/day administered to pregnant rats has been found teratogenic; doses of 1 or 10 µg/kg/day produced only subcutaneous edema. Daily doses of 10 and 100 µg/kg produce a positive response in chick edema bioassay, while doses of 0.1 and 1.0 µg/kg are negative.

Octachlorodibenzo-p-dioxin is much less toxic than the hexachloro isomers. Doses of 1 g/kg and 4 g/kg failed to kill female rats and male mice respectively. With regard to acnegenic activity, chloroform solutions containing 10-50 µg/ml are inactive. Studies to date have revealed that the octachloro isomer is essentially devoid of untoward activity in the embryo and fetus. Finally, the octachloro isomer does not produce chick edema.

Recent studies[95/] have indicated that the presence of these dioxins in commercial products can be responsible for certain adverse effects. "Commercial" PCP was compared to chemically pure PCP and an "improved" PCP. The relative dioxin contents of these products are presented in Table XLII, along with the results of the toxicity tests. Note that the "improved" pentachlorophenol does not elicit chick edema nor chloracne. In addition, the histopathological effects caused by impurities in commercial pentachlorophenol have been eliminated.

Over the past 30 years there has been much less "pure" penta marketed than is used today. However, there has been no record of industrial health problems among users in either the millwork industry or wood treating industry.

TABLE XLII

COMPARATIVE EVALUATION OF TOXICOLOGICAL DATA OBTAINED ON PENTACHLOROPHENOL SAMPLES

Dioxin Content		Commercial PCP	Chemically Pure PCP	Improved PCP
Hexachlorodibenzo-p-dioxins		19	0	1
Octachlorodibenzo-p-dioxin		1,980	0	30
Toxicity Study				
Chick Edema Bioassay		+	-	-
Rabbit Ear Bioassay		+	-	-
Rat Feeding Study				
Hematologic Depression		+	-	-
Clinical Chemistry-Alterations		+	-	-
Liver Damage (Histopathology)		+	-	-
Liver Weight Increase	30[a]	+	+	+
	10	+	+	+
	3	+	-	-
Kidney Weight Increase	30	+	+	+
	10	+	-	-
	3	+	-	-

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[a] Mg/kg/day.

Source: Dow Chemical Company (see text for reference).

CASE STUDY NO. 23 DICHLOROBENZENE

A. Product Description

Chemical Name: p-Dichlorobenzene; $C_6H_4Cl_2$

Trade Names: Many

Pesticide Class: Household Fumigant against moths. It is also widely used as lavatory space deodorant, and because potential impacts of this use may be indistinguishable from those of mothball application, it is included here.

Properties: Volatile white solid; Melting point 53°C; solubility in water, 80 ppm; soluble in alcohol, ether, benzene, chloroform

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Allied Chemical Corp.	Syracuse, N.Y.	14	10
Dover Chemical Corp.	Dover, Ohio	4	4
Dow Chemical Company	Midland, Mich.	16	16
Monsanto	Sauget, Ill	7	7
Olin Corp.	McIntosh, Ala.	--	7
PPG Industries, Inc.	New Martinsville, W. Va.	20	13
Standard Chlorine Company	Delaware City, Del.	20	15
			72*

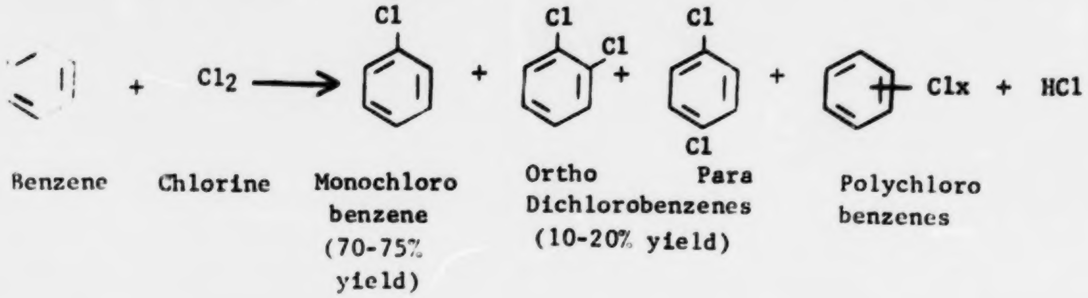
C. Production Methods and Waste Control Technology

Para-dichlorobenzene and ortho-dichlorobenzene are both produced almost entirely as by-products of the production of monochlorobenzene, which is currently at about the 400 million lb/yr. level, although decreasing.** The ortho- and para-dichlorobenzenes are obtained in approximately equal amounts, along with smaller amounts of tri- and tetra-chlorobenzenes and are separated by distillation. The proportion of by-product in monochlorobenzene production can easily be increased by longer chlorination. The reaction chemistry is as follows:

---

* The 72 MM lb. is based on the Tariff Commission's figure of 70.4 MM lb. for 1971 production, but additional quantities may be produced regularly as a reaction intermediate. Total annual production of p-dichlorobenzene may be as high as 100-110 MM lbs. according to one source.

** Monochlorobenzene production is expected to drop below 100 million lb/yr. by 1975 as producers of phenol (a major use of C_6H_5Cl) switch to the cumeme process.



A production and waste control schematic is shown in Figure 54.

Waste control technology: At Dow Chemical, the HCl by-product is apparently recycled to chlorine production while trichlorobenzenes are recovered. Dow says they have developed a proprietary process to reduce the so-called "tetra-tar" (which can run from 5-10% of the monochlorobenzene yield) back to dichlorobenzenes.

At Monsanto, the HCl is recovered as muriatic acid with only small amounts escaping through vents or going to a waste treatment plant. Polychlorobenzenes are not recovered and go to an approved landfill with other liquid plant wastes. The landfill is on Monsanto-owned land and is surrounded by wells that are periodically tested. Monsanto says that plans are being developed to incinerate their chlorobenzene wastes. The entire dichlorobenzene work area is ventilated and the air is monitored for p-dichlorobenzene levels. Ventilation air goes to a wet scrubber; the washwater collects little dichlorobenzene and is eventually discharged.

D. Formulation, Packaging and Distribution

Paradichlorobenzene has uses both as a consumer product and as a reactive intermediate. Its main use as a pesticide is in moth control* in woolen goods (where it acts as either a repellant or lavacide). It has wide use in toilet stool and urinal blocks (where it may retard odor-causing fungi or bacteria, as well as mask objectionable odors) and as a space deodorant or "air freshener". Paradichlorobenzene is sold in two purity levels: a product of $>99\%$ purity that is a solid at room temperature (the major impurity being the orthoisomer); and a product of $<99\%$ purity which is a liquid. The high purity material is required for the major consumer products.

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* It has had minor uses against Peach Tree Borers, bark bettles, tobacco blue mold, mildew and other fungi. It is a fungistat, not a fungicide.

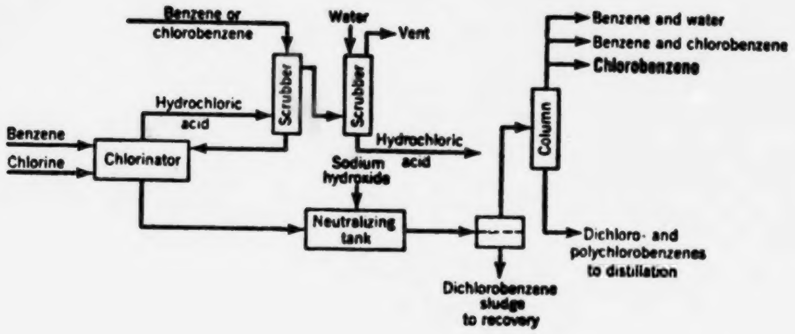

Benzene or chlorobenzene
Water
Vent
Benzene and water
Benzene and chlorobenzene
Chlorobenzene
Scrubber
Scrubber
Hydrochloric acid
Column
Benzene
Chlorine
Chlorinator
Hydrochloric acid
Sodium hydroxide
Neutralizing tank
Dichloro- and polychlorobenzenes to distillation
Dichlorobenzene sludge to recovery

Figure 54 - Production and Waste Schematic for p-Dichlorobenzene[75]

Monsanto produces p-dichlorobenzene only of 99.9% purity and markets most of it in the St. Louis area to several small companies that make consumer products. It is shipped in 200 lb. (55 gal) fiber-pack drums and also in tank trucks equipped with heating coils. The drums are one-way and combustible. Most of the tank trucks are leased (although Monsanto does have some) and are 100% dedicated to exclusive service where a contamination problem exists.

Dow produces p-dichlorobenzene as a 99.5% purity solid and a 96% purity liquid (both are said not to contain high chlorobenzenes) but does not produce any consumer products. Beginning in 1974, all of Dow's p-dichlorobenzene will be shipped as a liquid (using heated, insulated tank cars for the high purity product), but previously about half of it was sold as a solid, either in railroad cars or in 200 lb drums. The 99.5% product is sold to about 24 processors that have capacities of over 1 MM lb/yr each of consumer p-dichlorobenzene products. The 96% product is sold in part for industrial uses as a reactive intermediate and in part to semi-producers or refiners, who separate the ortho-dichloro- and trichlorobenzenes and sell 99% product to the processors, as well as products to industrial users.

Two major p-dichlorobenzene processors are: Chemical Products Corp. of Cartersville, Ga. (Capacity: ~ 3MM lb/yr) and Specialty Organics, of Los Angeles, Calif. (Capacity: ~ 3MM lb/yr). A major dichlorobenzene refiner is Solvent Chemical Co., Inc. of Niagara Falls, N.Y. (Capacity: 15-20MM lb/yr). In addition, Standard Chlorine, which is a prime producer may also buy and refine additional dichlorobenzenes.

p-Dichlorobenzene is used as a reactive intermediate in the production of agricultural pesticides (e.g. via 1,2,4-trichlorobenzene) dyestuffs, and other chemicals, and also for other minor industrial uses such as a porosity control agent (e.g. in the manufacture of grinding wheels). About 75% of the p-dichlorobenzene used for these purposes is consumed on the East Coast.

Of the total p-dichlorobenzene production, an estimated 25-30 million lbs/yr goes to moth control use (balls, crystal powders), 25-30 million for lavatory-space deodorant uses and the remainder for other purposes.

Orthodichlorobenzene, in contrast to the para-isomer, is used almost entirely as a reactive intermediate (60-75%) and for other industrial purposes (e.g. solvent component) although a small amount is used as a space deodorant. A substantial part of that used as a reactive intermediate is converted to pesticide (e.g. via chloroaniline to diuron and linuron). Total production of orthodichlorobenzene according to the Tariff Commission was 53.6MM lb. in 1971, but one source has estimated total production for 1972 at nearly 100 MM lb.

E. Use Patterns

General : Para-dichlorobenzene in its solid form, > 99% purity, is used for moth control and space-deodorants and sublimes at 50°F to a heavier-than-air vapor.

Action : Fumigant against moths and their larvae, vapors act as a space deodorant, and a fungistat.

Application : As a moth control agent, a usage of 1 lb./100 cubic feet of confined space is recommended. Para-dichlorobenzene is sold in various sizes and shapes for lavatory space deodorants as the area requires.

Rate of Application : The p-dichlorobenzene should be kept at a level such that fumes in the confined area are concentrated enough to cause irritation to the eyes. This level is sufficient to maintain the fungistat properties. p-Dichlorobenzene requires replacement at varying intervals dependent upon sublimation rate.

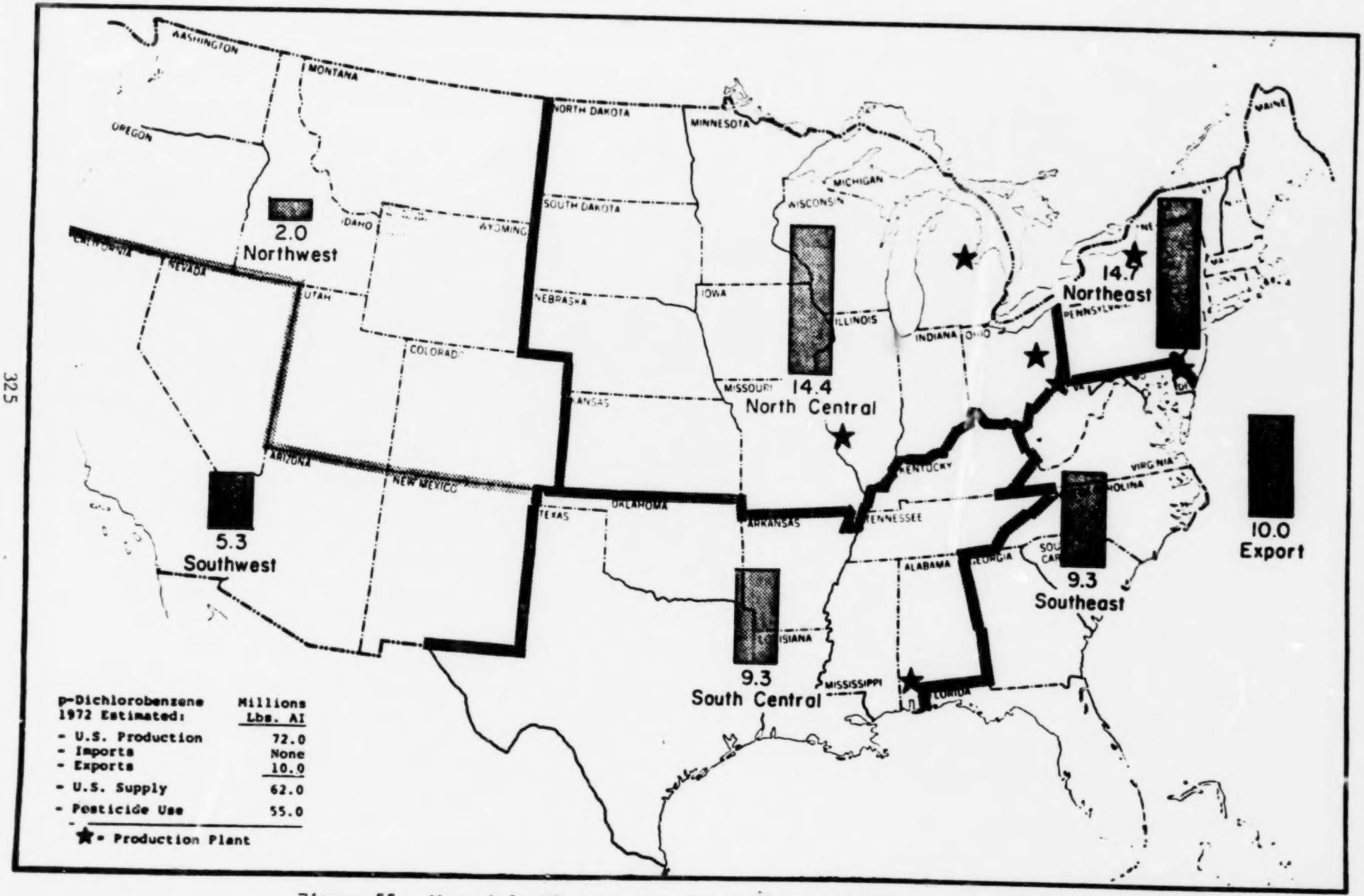
Estimated Distribution : (All figures in millions of lb/yr of A.I., 1972).

United States Production	Imports	Exports	Domestic Consumption
72	Nil.	10	55 (moth control and lavatory-space deodorant purposes only)

Pesticidal Use by Category and Geographical Region

Region	Agric.	Industrial/ Commercial	Govt	Home & Garden	Total
NE	Negl.	4	0.7	10	14.7
SE		2	0.3	7	9.3
NC		4	0.4	10	14.4
SC		2	0.3	7	9.3
NW		0.5	0.1	1.4	2.0
SW		1.5	0.2	3.6	5.3
Totals	Negl.	14.0	2.0	39.0	55.0

A materials flow diagram for p-dichlorobenzene is shown in Figure 55.



WASHINGTON
MONTANA
OREGON
IDAHO
WYOMING
CALIFORNIA
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
PENNSYLVANIA
MAINE
2.0
Northwest
5.3
Southwest
14.4
North Central
9.3
South Central
14.7
Northeast
9.3
Southeast
10.0
Export
p-Dichlorobenzene 1972 Estimated:
Millions Lbs. AI
- U.S. Production 72.0
- Imports None
- Exports 10.0
- U.S. Supply 62.0
- Pesticide Use 55.0
★ - Production Plant

Figure 55 - Materials Flow Diagram for p-Dichlorobenzene

F. Alternatives

Chemicals : Naphthalene can be a moth fumigant but requires a usage of 5 lb/100 cu ft confined space; other space-odorants are available but none are as effective or inexpensive as p-dichlorobenzene.

Nonchemical : There are no specific, practical, nonchemical alternatives.

G. Environmental Impact Potential

Mammalian Toxicity : The oral acute LD_{50} of p-dichlorobenzene to rats is 2,620 mg/kg and for mice, 2,950 mg/kg placing it in the slightly toxic range. The minimum dermal lethal dose for rabbits is > 1,260 mg/kg.

In humans, it causes moderate irritation to the eyes, throat, nose, skin (but is not absorbed). In general, there are no problems unless exposure is prolonged and usually severe. Persons suffering from acute or chronic liver or kidney disease, or from alcoholism are advised to avoid frequent exposure. Continued exposure to vapors for months or years may cause headache, portal cirrhosis, or atrophy of liver, and no specific antidote is known.

Nontarget Organisms : There are no data on toxicity to fishes, wild mammals, or soil organisms. However, p-dichlorobenzene is known to be relatively nontoxic to lower aquatic organisms and moderately toxic to birds. It does not buildup in the food chain.

Environment : Para-dichlorobenzene undergoes degradation at a moderate to rapid rate. It is degradable by biological organisms, nonbiological factors, and sunlight. The major degradation products are 2,5-dichlorophenol, dichloroquinol, and conjugates. There are no data as to persistence in soil. It has also been detected in water supplies.

Evaluation : Para-dichlorobenzene is irritating to eyes, mucous membranes, and skin only at levels not ordinarily voluntarily tolerated by humans. It has been cleared of the suspicion that it may produce cataracts in man. However, when used as specified, it provides relatively safe and inexpensive moth protection and space deodorant properties.

CASE STUDY NO. 24 METHYL BROMIDE

A. Product Description

Chemical Name: Bromomethane

Trade Names: Bromo-O-Gas, Dowfume MC-2, Dowfume MC-33, MeBr, Meth-O-Gas, Profume

Pesticide Class: Fumigant; Halocarbon

Properties: Liquified gas (BP 3.6°C); very toxic; probably not persistent in sunlight

B. Manufacturers

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Dow Chemical Company	Midland, Michigan	15 million lb	13 million lb
Michigan Chemical Corporation	St. Louis, Michigan	3 million lb	2 million lb
Kerr-McGee Corporation	Los Angeles,[a] California	2.5 million lb	2 million lb
Great Lakes Chemical	El Dorado, Arkansas	10 million lb	8 million lb

C. Production Methods and Waste Control Technology

Information on Dow's production method and waste control technology for methyl bromide has been reported.[1] The reaction chemistry is:

$$6\ CH_3OH + 3Br_2 + S \longrightarrow 6CH_3Br + H_2SO_4 + 2H_2O$$

A production and waste schematic for Dow's process is shown in Figure 56.

Methyl bromide is colorless, odorless, poisonous gas which must be handled in a closed, refrigerated system. Dow receives the raw products for the production of methyl bromide in tank cars or trucks. The H_2SO_4 by-product is recovered and sold. Another possible by-product is $(CH_3)O$.

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[a] This plant was moved to Trona, California, after 1972.

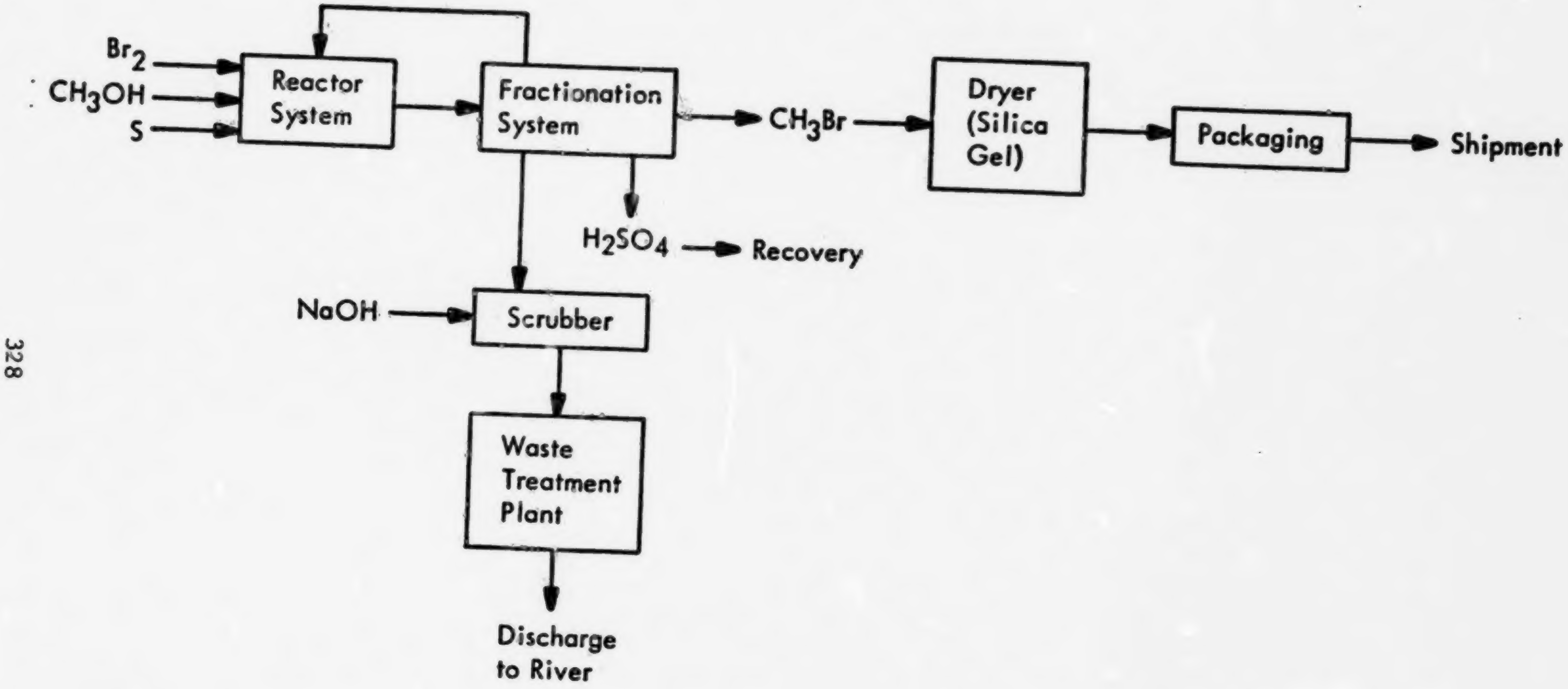
Br_2
CH_3OH
S
Reactor System
Fractionation System
CH_3Br
Dryer (Silica Gel)
Packaging
Shipment
H_2SO_4
Recovery
NaOH
Scrubber
Waste Treatment Plant
Discharge to River

Figure 56 - Production and Waste Schematic for Methyl Bromide (Dow Chemical)1/

Dow has ~ 90% CH_3Br recovery on the first pass. The CH_3Br system is vented through a caustic scrubber and the product is dried with silica gel. Containers are checked for leaks and a lacrymator is added as a warning agent.

D. Formulation, Packaging, and Distribution

The technical product is available in 1-lb cans (over 5 million per year), 10-, 50-, 100-, and 50-lb cylinders, 1,500-lb pigs, and 13,000-lb cylinders used in exportation. Dow provides the following formulations: Profume®--98% methyl bromide plus 2% chloropicrin (a lacrymator added as a leakage-warning agent), methyl bromide (100%), Dowfume® MC-2--98% AI, and Dowfume® MC-33--67% methyl bromide and 33% chloropicrin.

Methyl bromide is also available is formulations with 26% AI, and in combinations with ethylene dibromide and with hydrocarbons.

E. Use Patterns

General : Methyl bromide is a volatile chemical of low molecular weight and high vapor pressure, for application into stacks of stored products in confined spaces or into the soil, for the destruction of insects, nematodes, weeds, soil pathogens, and other pest organisms. Fumigants such as methyl bromide penetrate quickly into stacks of stored products or into cracks and crevices and are preferred for the treatment of commodities and containers or enclosed spaces that can be sealed completely.

Action : Methyl bromide is a general biocide that destroys exposed organisms by fumigant action.

Uses : Soil fumigants - tobacco and vegetable seed beds, other seed beds, greenhouses. Fumigation of grains and other commodities. Used in grain elevators, mills, warehouses, vaults, shipholds, freight cars, etc.

Target Pests : Insects, rodents, nematodes, soil pathogens, weed seeds, etc.

Rates of Application: 1-2 lb/1,000 cu ft for commodities, 300-600 lb AI/acre for soil fumigation.

Frequency : For protection of stored products: as required, 1-3 applications per year. Soil fumigation: one treatment per vegetation season.

Time of Application : Variable for stored products protection. Prior to planting for soil fumigation.

Estimated Distribution : (All figures in millions of lb AI/year, 1972).

U.S. Production	Imports	Exports	Domestic Consumption
25	Negl.	2	23

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGION

Region	Agricultural	Industrial, Commercial	Government Agencies	Home and Garden	Totals
NE	0.6	0.8			1.4
SE	2.7	2.5			5.2
NC	0.3	6.0			6.3
SC	0.9	2.5			3.4
NW	0.2	0.8			1.0
SW	4.3	1.4			5.7
Totals	9.0	14.0	Negligible	Negligible	23.0

A materials flow diagram for methyl bromide is shown in Figure 57.

F. Alternatives

Chemicals : Other fumigants including ethylene oxide, hydrogen cyanide, hydrogen phosphide, ethylene dibromide, ethylene dichloride, and others.

Nonchemical : There are no nonchemical means for the destruction of stored products pests. General sanitation is usually not sufficient to prevent invasion of stored products by such pests. Limited volumes of soil can be sterilized by steam.

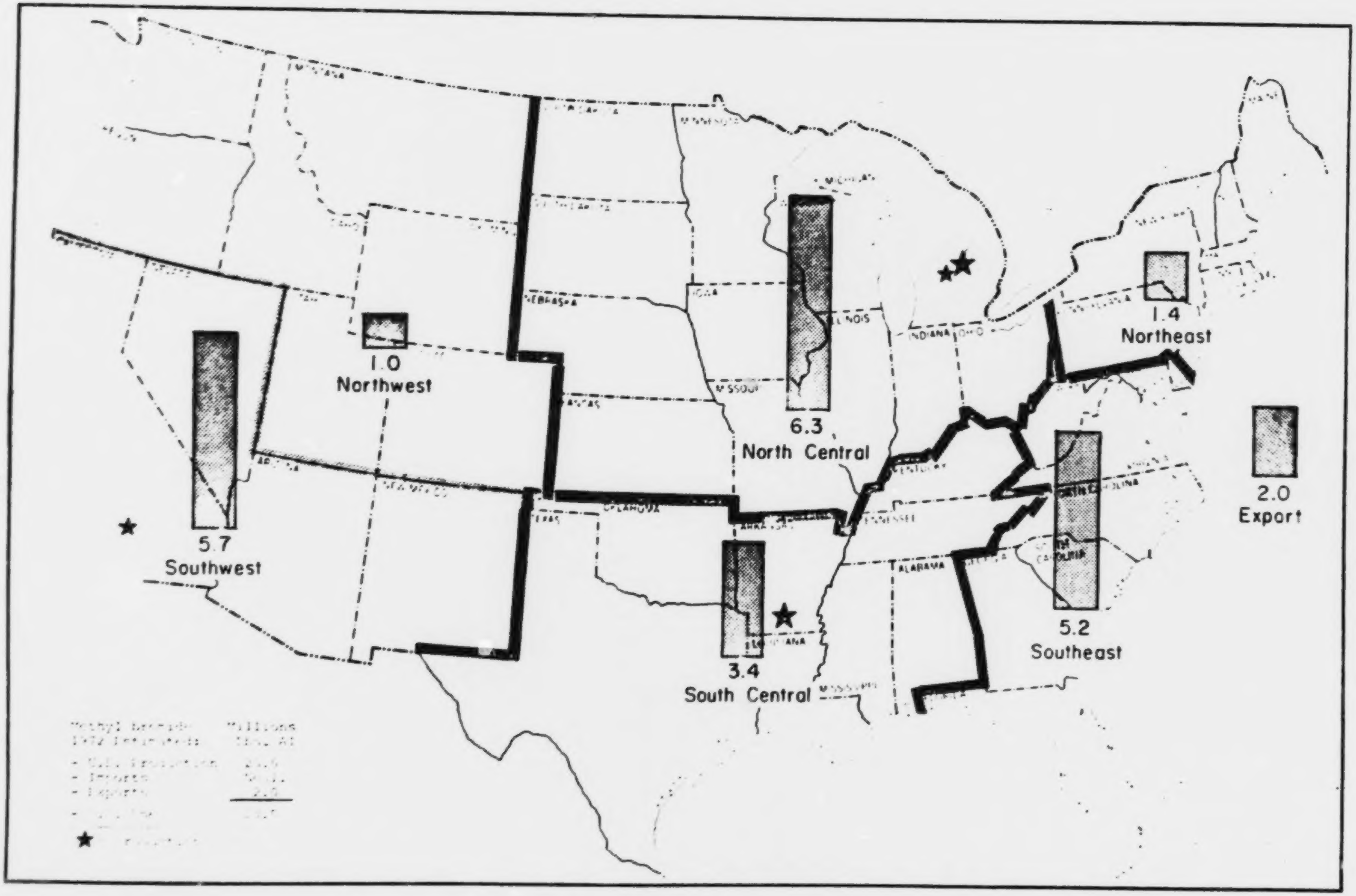
1.0
Northwest
5.7
Southwest
6.3
North Central
3.4
South Central
1.4
Northeast
5.2
Southeast
2.0
Export
Methyl Bromide
Millions
- Imports
- Exports
2.0

Figure 57 - Materials Flow Diagram for Methyl Bromide, 1972

G. Environmental Impact Potential

Mammalian Toxicity : Methyl bromide is a highly toxic chemical. Since it is a gas at ambient temperatures, acute oral toxicity tests are not pertinent. Skin contact causes severe burns. It is highly toxic by inhalation. Methyl bromide is severely irritating to eyes, nose, throat and skin. In mammals, methyl bromide will produce respiratory embarrassment, cardiac arrest, and central nervous system irritation. It requires labeling as a poisonous gas, including skull and crossbones and the signal word "Danger - Poison". Repeated exposures to methyl bromide cause cumulative toxic effects, including severe lung irritation and damage to kidneys and the nervous system.

Inorganic bromides are found as residues in commodities fumigated with methyl bromide. In chronic feeding studies, 40.0 mg/kg/day of bromide fed to rats showed no effect. Residue tolerances for inorganic bromides resulting from the use of methyl bromide have been established for many commodities, ranging from 5 to 400 ppm, 20 to 50 ppm for most.

Methyl bromide may be used only by trained professional operators.

Nontarget Organisms : Methyl bromide is highly toxic to most or all forms of life. Nontarget organisms such as fishes, lower aquatic organisms, birds, wild mammals and soil organisms outside of treated areas will not ordinarily come in contact with it. There is no build-up in food chains.

Environment : Methyl bromide itself is not persistent. Since it is applied as a gas, it disperses quickly into the atmosphere unless confined. Its rate of volatilization is high, but it is not likely to move away from treated areas by leaching or surface run-off in water or on solids.

Methyl bromide is degraded to inorganic bromides which are persistent chemicals. Inorganic bromides may persist in treated soils and carry over to the following vegetation season.

Evaluation : Methyl bromide is a highly toxic poison that should be used only by trained professionals. Handling by inexperienced persons invites disaster. Aside from these operator hazards, there are no indications of other serious hazards to human health or to nontarget organisms, provided the product is used strictly in accordance with the label directions. No data are available on the possible soil accumulation of inorganic bromides from repeated soil fumigant use of methyl bromide, or on the possible effects of bromide residues on the environment in or near areas of extensive use.

CASE STUDY NO. 25 ORGANOTIN COMPOUNDS

A. Product Description*

Chemical Name: Tricyclohexyltin hydroxide

Trade Names: Plictran, Dowco 213

Pesticide Class: Acaricide

Properties: White crystals, m.p. 195-197°C, nearly insoluble in water, soluble in most organic solvents.

Chemical Name: Triphenyltin hydroxide (fentin hydroxide)

Trade Names: Du-Ter, TPTH

Pesticide Class: Nonsystemic fungicide

Properties: White powder, m.p. 118-124°C, insoluble in water, moderately soluble in most organic solvents.

Chemical Name: Bis(tributyltin) oxide (TBTO)

Trade Names: Butinox, Keycide X-10, Car-Ban T-O, Vikol, Aducide 340-A

Pesticide Class: Fungicide and antifoulant

Properties: Colorless to slightly yellow liquid, b.p. 210-214°C at 10 mm Hg, insoluble in water, soluble in most organic solvents.

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* Of the many known organotin compounds, only tricyclohexyltin hydroxide, triphenyltin hydroxide, and bis(tributyltin) oxide are commercially important pesticides in the United States at present, although some other organotins have larger industrial uses, e.g., as stabilizers or curing agents in plastics.

B. Manufacturers and Formulators

Name	Plant Location	Plant Capacity	Estimated 1972 Production
Organotin Manufacturers			
M & T Chemicals, Inc. Subisdiary of American Can Company	Rahway, New Jersey	(Unavailable, See Section C)	
Organotin Pesticide Formulators			
Dow Chemical Company	Midland, Michigan	Unavailable See Section C	0.4 million lb
Thompson Hayward Chemical Company	Kansas City, Kansas	Unavailable See Section C	0.6 million lb
Cincinnati Milacron Chemicals,	Reading, Ohio	Unavailable See Section C	0.8 million lb
Vikon Chemical Company, Inc.	Elon College, North Carolina	Unavialable See Section C	
Witco Chemical	Chicago, Illinois	Unavailable See Section C	

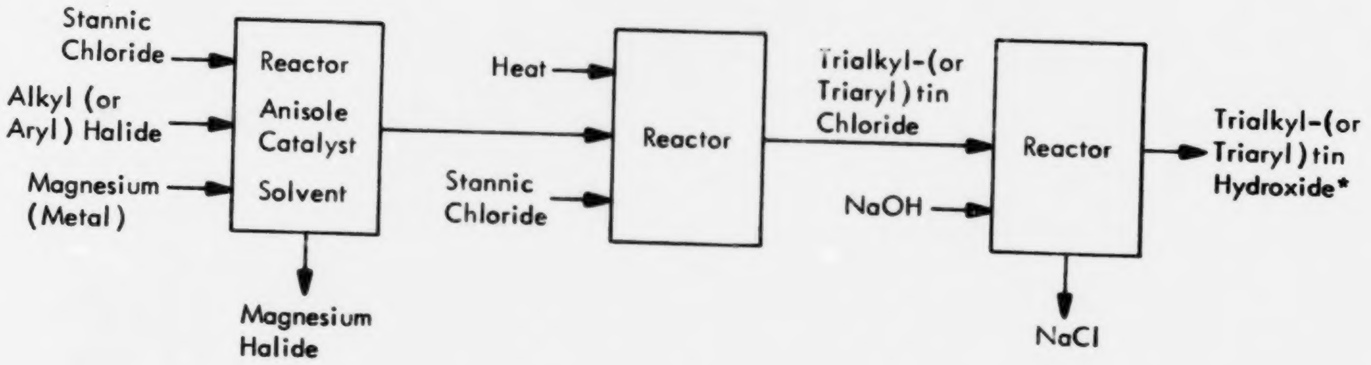
M & T is currently the largest industrial producer of organotin compounds, most of which are used for nonpesticidal purposes. Other producers are Cardinal Chemical, Columbia, South Carolina; Ferro, Cleveland, Ohio; Cincinnati Milacron, Reading, Ohio; and Argus, a division of Witco Chemical. M & T sells all of their production to other companies, including the three organotins being considered herein.

C. Production Methods and Waste Control Technology

M & T declined to provide information on its manufacturing process or waste control technology, but the equation below and the schematic shown in Figure 58 are believed to be representative.

The reaction most often used is as follows:

$$\underset{\text{(Alkyl or Aryl Halide)}}{4\ \mathrm{RCl}} + \mathrm{Mg} + \mathrm{SnCl_4} \xrightarrow[\text{solvent}]{\text{catalyst}} \mathrm{R_4Sn} \xrightarrow{\mathrm{SnCl_4}} \mathrm{R_3SnCl} \xrightarrow{\mathrm{NaOH}} \begin{array}{c}\mathrm{R_3SnOH} \\ \text{or} \\ \mathrm{R_3SnOSnR_3}\end{array}$$


Stannic Chloride
Alkyl (or Aryl) Halide
Magnesium (Metal)
Reactor
Anisole Catalyst
Solvent
Magnesium Halide
Heat
Stannic Chloride
Reactor
Trialkyl-(or Triaryl) tin Chloride
NaOH
Reactor
NaCl
Trialkyl-(or Triaryl) tin Hydroxide*

* In the Case of Tributyltin Chloride, the Hydrolysis Produces Bis (Tributyltin) Oxide.

Figure 58 - Production and Waste Schematic for Organotin Compounds

The following methods are also used in the U.S. to prepare R_4Sn:

Wurtz Reaction

$$SnCl_4 + 4RCl + 8Na \longrightarrow R_4Sn + 8NaCl$$

Aluminum-Alkyl Technique

$$3SnCl_4 + 4R_3Al \longrightarrow 3R_4Sn + 4AlCl_3$$

D. Formulation, Packaging, and Distribution

1. Tricyclohexyltin hydroxide: Dow purchases a 90-95% technical grade tricyclohexyltin hydroxide in 75 lb fiber drums from M & T Chemical Company. Dow then formulates it into a 50% WP and a 25% WP at the Midland, Michigan facilities in dedicated equipment.

Plictran (Dow's trade name) 50% WP is sold in the U.S. and packaged in 2 lb bags, 12 to a case. Plictran 25W is shipped overseas. Dow also produces 25W in the Netherlands.

Plictran is used primarily on the West Coast, and in New York, Pennsylvania, Virginia, and Florida. It is a miticide only.

2. Triphenyltin hydroxide (Fentin hydroxide): Thompson-Hayward purchases the triphenyltin hydroxide active ingredient from M & T Chemical Company in 200 lb fiberboard "kits" (drums). Formulation to Du-Ter® by Thompson-Hayward is in an isolated area and in dedicated equipment.

T-H makes only one formulation, a 47.5% WP which has a patented "safening agent" to reduce phytotoxicity, as well as wetting agents, emulsifiers, etc. The recycled bulk hoppers are used to ship the fentin hydroxide to Iowa for packaging and distribution. Packages are polyethylene, with a water soluble inner liner, and are of two sizes: 1 lb and 30 oz bags. The user can place Du-Ter, liner and all, in the mix tank. Bags are shipped by truck; 24/case for the 1 lb size and 10-12/case for the 30 oz bags.

Triphenyltin hydroxide has heaviest use in the Southeast and Northwest, appreciable amounts across the North Central and South Central and some in central California; very little is used in the East or in the cornbelt.

3. Bis(tributyltin) oxide (TBTO): Bis(tributyltin) oxide is sold by M & T Chemical Company as an unformulated, water insoluble liquid containing 95% AI. In this form it is used as an antifouling agent for marine paint and in applications where adsorption to cellulosic materials is desirable, for example, for odor control on washed fabrics and wood preservation. For other applications such as paper mill slime control or as a fungicide in industrial cooling water, the product is sold as a water-soluble or water-dispersible form by incorporating cationic or nonionic surfactants into the formulation. Witco, a major formulator of TBTO, markets Keycide X-10® with 12% AI. Witco recommends that TBTO be used in polyvinyl acetate latex paints at about 0.7 lb AI/100 gal. of paint.

E. Use Patterns

1. Tricyclohexyltin hydroxide:

General: Tricyclohexyltin hydroxide (Plictran) is a recently-developed, selective miticide. It is the first and, thus far, the only organotin compound in its field. It controls strains of plant-feeding mites resistant to other miticides. It is less toxic to predatory (beneficial) mites and relatively harmless to honeybees and other insects. These properties allow its use in integrated pest management programs. The product has been used overseas for several years, but was registered in the U.S. only in 1972. Its use is expected to increase.

Action: Contact miticide, controls motile forms of mites, but has no ovicidal action (i.e. does not kill mite eggs).

Target crops: Apples, pears, nonbearing citrus, certain ornamentals.

Target pests: Phytophagous (plant-feeding) mites.

Application: Foliar application by ground equipment

Rates of application: 1-4 lb AI/acre, or 4-6 oz AI/100 gal. of spray.

Frequency: 1-4 applications per season.

Time of application: Late spring to close to harvest on deciduous fruits; spring and fall on citrus fruits.

2. Triphenyltin hydroxide (Fentin hydroxide):

General: Triphenyltin hydroxide (Du-Ter) is one of a group of organotin compounds that were developed primarily in Europe. It is the only organotin fungicide currently in use in agriculture in the United States. Triphenyltin hydroxide is an extremely effective fungicide, as evidenced by the very low dosage rates required for control of the target fungus diseases.

Action: Contact fungicide, broad spectrum; protective and curative action.

Target crops: Peanuts, pears, potatoes, sugar beets, tobacco, carrots.

Target diseases: Cercospora leaf spot; Alternaria (brown spot on tobacco; blight on potatoes and carrots); late blight; scab, brown leaf spot, downy spot, leaf blotch, powdery mildew and other diseases on pecans.

Application: Foliage sprays by ground or air equipment.

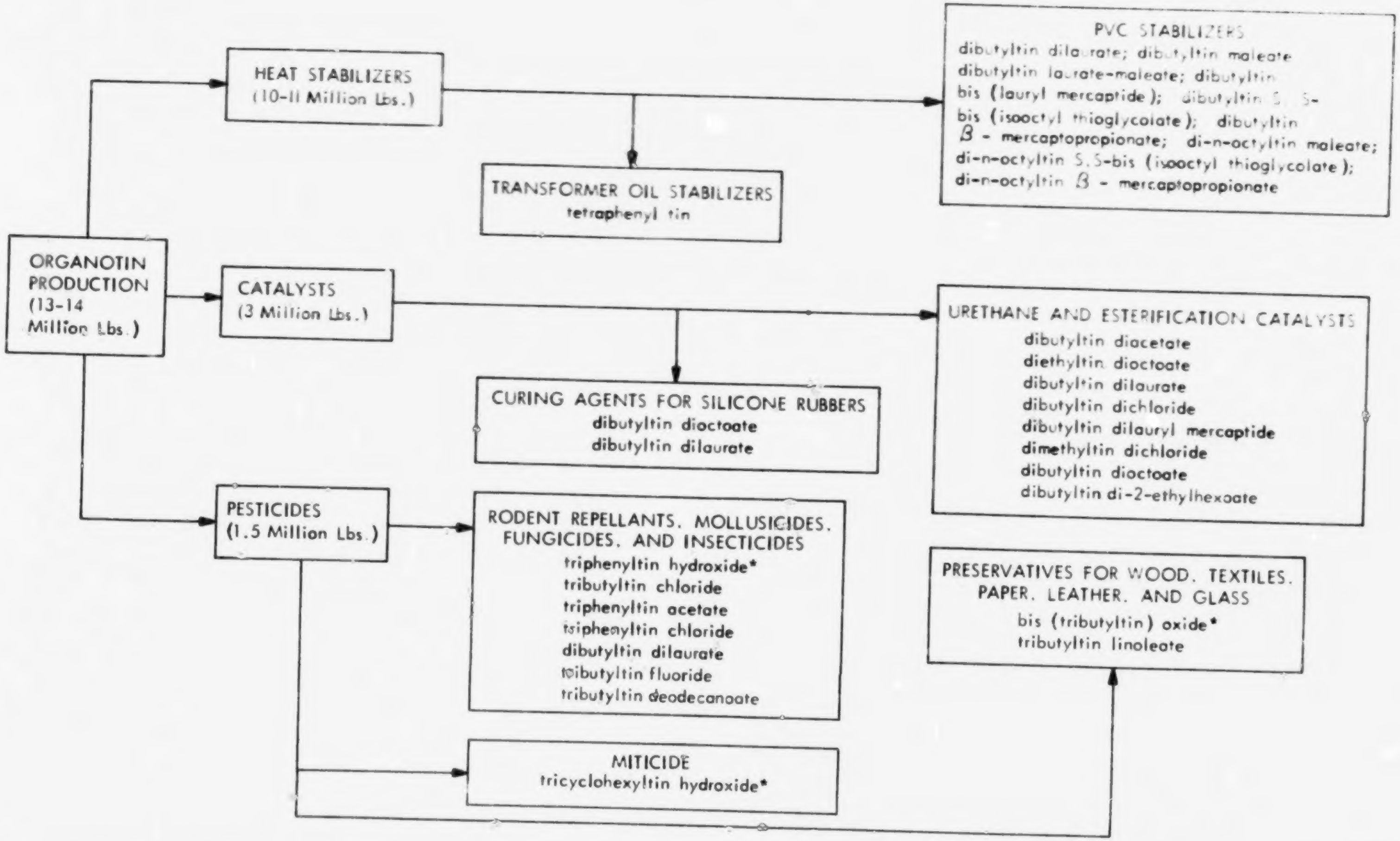
Rates of application: 2-5 oz AI/acre or 100 gal. for row crops; 6-12 ox AI/acre for pecans.

Frequency: Multiple treatments at 7-14 day intervals, as required.

Time of application: Throughout the growing season.

3. Bis(tributyltin) oxide: Bis(tributyltin) oxide, TBTO, gives antibacterial, antifungal, and mothproofing properties to treated fabrics. TBTO is effective in controlling bacteria in hospitals, such as Staphylococcus aureus. TBTO has also been used to prevent odors in garbage pails, control athlete's foot, control molds in bathrooms, control mildew on leather goods, textiles, and plastics, and mothproof stored garments. TBTO is an active ingredient in marine lumber preservation. Paint formulations containing TBTO have controlled marine fouling for as long as cuprous oxide paints. Industrial applications of TBTO include its use for slime control in paper pulp mills and cooling towers.

4. Production of organotin compounds: Figure 59 illustrates the overall production and use of organotin compounds. Pesticidal applications are seen to be relatively small compared to the use of these compounds for other pruposes. The three compounds chosen for this study represent the major proportion of organotin compounds currently used in pesticidal applications. The use of these three compounds is summarized in Table XLIII and the geographical distribution of this use is summarized below. Because the pesticidal use of organotins is small compared to overall use, a materials flow diagram is not warranted.


ORGANOTIN PRODUCTION (13-14 Million Lbs.)
HEAT STABILIZERS (10-11 Million Lbs.)
CATALYSTS (3 Million Lbs.)
PESTICIDES (1.5 Million Lbs.)
TRANSFORMER OIL STABILIZERS
tetraphenyl tin
PVC STABILIZERS
dibutyltin dilaurate; dibutyltin maleate
dibutyltin laurate-maleate; dibutyltin
bis (lauryl mercaptide); dibutyltin S, S-
bis (isooctyl thioglycolate); dibutyltin
β - mercaptopropionate; di-n-octyltin maleate;
di-n-octyltin S,S-bis (isooctyl thioglycolate);
di-n-octyltin β - mercaptopropionate
CURING AGENTS FOR SILICONE RUBBERS
dibutyltin dioctoate
dibutyltin dilaurate
URETHANE AND ESTERIFICATION CATALYSTS
dibutyltin diacetate
diethyltin dioctoate
dibutyltin dilaurate
dibutyltin dichloride
dibutyltin dilauryl mercaptide
dimethyltin dichloride
dibutyltin dioctoate
dibutyltin di-2-ethylhexoate
RODENT REPELLANTS, MOLLUSICIDES, FUNGICIDES, AND INSECTICIDES
triphenyltin hydroxide*
tributyltin chloride
triphenyltin acetate
triphenyltin chloride
dibutyltin dilaurate
tributyltin fluoride
tributyltin deodecanoate
MITICIDE
tricyclohexyltin hydroxide*
PRESERVATIVES FOR WOOD, TEXTILES, PAPER, LEATHER, AND GLASS
bis (tributyltin) oxide*
tributyltin linoleate

* Organotin Compounds Included in Intensive Study

Source: MRI estimates and W. T. Piver, Environmental Health Perspectives Exp. Issue No. 4 June 1973 p61

Figure 59 - Estimated Production and Use of Organotin Compounds

TABLE XLIII

ESTIMATED U.S. USES OF SELECTED ORGANOTIN PESTICIDES

(In Thousands of Pounds of Active Ingredients)

	Fentin Hydroxide ("Du-Ter")	Tricyclohexyltin Hydroxide ("Plictran")	Bis(tributyltin) Oxide (TBTO)	Totals
Production	0.60	0.40	0.80	1.80
Export	Negl.	0.35	Negl.	0.35
Import	Negl.	None	Negl.	Negl.
U.S. Uses	0.60	0.05	0.80	1.45

Estimated distribution: (All figures in millions of pounds AI/year, 1972).

DOMESTIC USE BY CATEGORY AND GEOGRAPHIC REGIONS

Region	Agricultural	Industrial/ Commercial	Government Agencies	Home and Garden	Totals
Tricyclohexyltin hydroxide					
NE	0.01	Negligible	Negligible	Negligible	0.01
SE	0.01				0.01
NC	< 0.003				< 0.003
SC	< 0.003				< 0.003
W	0.03				0.03
Totals	0.050	--	--	--	0.050
Triphenyltin hydroxide					
NE	0.02	Negligible	Negligible	Negligible	0.02
SE	0.20				0.20
NC	0.08				0.08
SC	0.20				0.20
W	0.10				0.10
Totals	0.600	--	--	--	0.600
Bis(tributyltin) oxide					
NE	Negligible	0.2	Negligible	Negligible	0.2
SE		0.1			0.1
NC		0.2			0.2
SC		0.1			0.1
W		0.2			0.2
Totals	--	0.80	--	--	0.80

F. Alternatives to Use

1. Tricyclohexyltin hydroxide:

Chemicals: A number of other chemical miticides provide control of plant-feeding mites. However, many strains of mites in many areas have become highly resistant against individual miticides or groups of chemically related products. Tricyclohexyltin hydroxide is unique because of its novel chemistry. Its spectrum of efficacy on mites is not duplicated by any other currently available product.

Nonchemical: Plant-feeding mites have a number of natural enemies, including predatory mites and fungi. When these are removed from an ecosystem by the use of pesticides or otherwise, populations of plant-feeding mites often build up to damaging levels. There are currently no specific, direct nonchemical counter-measures available to fruit or vegetable growers once this occurs. Integrated pest management procedures should be used to prevent build-up of plant-feeding mites.

2. Triphenyltin hydroxide:

Chemicals: Dithiocarbamate fungicides; copper fungicides; chlorothalonil (Bravo, Daconil); benomyl (Benlate); dodine (Cyprex), thiabendazole (Mertect); others.

Nonchemical: There are no specific, practical, nonchemical alternatives for control of the plant diseases controlled by these fungicides.

3. Bis(tributyltin) oxide (TBTO): As an antibacterial, antifungal and mothproofing agent, TBTO competes with such compounds as copper 8-quinolinolate, copper and zinc naphthenates, zinc dimethyldithiocarbamate, pentachlorophenol, and quaternary ammonium compounds. The main disadvantage of TBTO is cost, but its major advantage is that it is colorless and will not produce stains. As an antifoulding agent for paint, TBTO competes with organomercurials and organolead. In the control of slime in cooling towers,. TBTO must compete with less costly, highly effective, but hazardous compounds such as trichlorophenol and organomercurials.

G. Environmental Impact Potential

1. Tricyclohexyltin hydroxide:

Mammalian toxicity: Tricyclohexyltin hydroxide is slightly toxic to laboratory animals via the oral and dermal routes, moderately toxic by way of inhalation exposure. The chemical is irritating to the eyes and to the skin. Sensitization has not been observed in laboratory tests or in field experience. There are no reports of cumulative toxic effects. The signal word "Caution" is required for labeling of the 50% wettable powder formulation, the form most commonly used in the U.S.

In chronic toxicity tests, the highest no-effect levels observed were 6 mg/kg of body weight per day for rats, 3 mg/kg of body weight per day for dogs. Tolerances for residues of tricyclohexyltin hydroxide have been established at 2 ppm for apples, pears and citrus, 8ppm for dried apple pomace and citrus pulp.

Nontarget organisms: Tricyclohexyltin hydroxide is moderately toxic to fishes, relatively nontoxic to birds and wild mammals. No data are available on its toxicity to lower aquatic organisms, soil organisms, or on its possible build-up in food chains.

Tricyclohexyltin hydroxide is relatively nontoxic to predatory mites, and to honeybees and other insects.

Environment: Tricyclohexyltin hydroxide is a moderately stable chemical. It is not recommended for application directly to the soil. It dissipates within days or weeks from plant surfaces, depending on weather and other conditions. Half-life in orchard soils ranges for 2 to 6 months; there may be some carry-over of soil residues to the following season. It is believed that degradation in the environment occurs through photodecomposition, microbial activity, and chemical hydrolysis. Degradation products include dicyclohexyltin oxide (comparable in toxicity to the parent pesticide) and cyclohexylstannoic acid, eventually inorganic tin.

Tricyclohexyltin hydroxide may volatilize to some extent from moist (not from dry) surfaces. Based on field tests, leaching does not occur. Surface run-off in water is unlikely due to very low water solubility, but htere may be migration away from target areas by way of soil erosion of material adsorbed on soil solids.

Evaluation: Tricyclohexyltin hydroxide formulations may cause eye or skin irritation to operators. There are no indications of other serious hazards to human health from the use of this chemical as an agricultural miticide.

The chemical is toxic to fishes. Data on toxicity to lower aquatic organisms and to soil organisms are incomplete at this time. Water contamination in concentrations that would be acutely harmful to aquatic ecosystems is unlikely to result from proper use of the product in accordance with label directions.

2. Triphenyltin hydroxide (Fentin hydroxide):

Mammalian toxicity: Results of acute toxicity tests indicate that triphenyltin hydroxide falls into the "moderately toxic" category. It is only slightly toxic to rabbits via the dermal route. The active ingredient is severely irritating to eyes, nose, throat and skin. Labels of the 47.5% wettable powder formulation carry the signal word "Caution". In chronic toxicity tests, the no-effect level to rats was 1.0 ppm, to dogs 2.5 ppm. No cumulative toxic effects have been reported. Residue tolerances ranging from 0.05 to 0.4 ppm have been established.

Nontarget organisms: Triphenyltin hydroxide is highly toxic to fishes and lower aquatic organisms, and relatively nontoxic to birds and soil organisms. No data are available on its toxicity to wild mammals, or on possible food chain build-up.

Environment: Triphenyltin hydroxide is not recommended for any applications directly to the soil. No data are available on its possible migration away from treated areas by volatilization, leaching, surface runoff, or wind erosion. Triphenyltin hydroxide is moderately stable; its half-life in the soil has been estimated at 2-3 months. There are no problems of carryover to the following vegetation season. It is believed that triphenyltin hydroxide is degraded in the environment to inorganic tin and CO_2, but the exact mechanisms and pathways are not known.

Evaluation: Triphenyltin hydroxide formulations may cause skin irritation and/or irritation of mucuous membranes in persons handling it. There are no indications of other serious hazards to humans from its use as an agricultural fungicide in accordance with label directions.

Triphenyltin hydroxide is highly toxic to aquatic organisms including fishes. However, water contamination in concentrations that would be acutely harmful to such organisms is not likely to occur if the product is used properly. Triphenyltin hydroxide is a moderately persistent, highly effective biocide, but it is used at very low rates of application. Triphenyltin hydroxide products are relatively expensive to the user. This is an effective deterrent against overuse or unnecessary use.

3. Bis(tributyltin oxide (TBTO):

Mammalian toxicity: Bis(tributyltin) oxide is moderately toxic orally in rats; the acute oral LD_{50} of TBTO on rats is approximately 200 mg/kg. The acute dermal LD_{50} established on albino rabbits is in the range of 11,700 mg/kg. In its undiluted form (95%), TBTO is a primary skin irritant. It has not been firmly established, by controlled experiments, whether or not TBTO is a skin sensitizer. However, extensive tests have established that less than 500 ppm on a textile has no adverse effect on the skin. This dosage is based on the weight of the textile.

TBTO is extremely hazardous to the eyes. Upon contact it may cause damage if not treated promptly.

APPENDIX A

CRITERIA FOR SELECTION OF PESTICIDES FOR INTENSIVE STUDY

A systematic effort was made to select approximately 25 pesticides for intensive study on this project. A goal was to select major pesticides that would be representative of all the diverse uses of pesticides.

A preliminary rating was made for over 85 pesticides, based on estimated production volume, use patterns, environmental concern and other criteria. These ratings were reviewed with project officers from CEQ and EPA; the weightings of certain criteria were revised slightly, a few new criteria were added, and additional pesticides were suggested.

Approximately 125 pesticides were then divided according to activity type (insecticides, herbicides, etc.) and chemical class and rated with the results shown in Table A-I. A summary of these ratings is shown in Table A-II and the recommended pesticides are listed in Table A-III. The guidelines for ratings are shown below. At the suggestion of EPA officials the organotin compounds were selected in place of the copper compounds.

TABLE 4-7

PESTICIDE PRIORITY RATING

Part A - Insecticides

Characteristic / Rating Scale / Pesticide	Production and Use						Environmental Concern									Regulatory Interest				Other Criteria						
	Production or Import, Total	Ind., Comm., and Inst. Use	Agricultural Use	Governmental Use	Home and Garden Use	Export and Other Use	Toxicity, Mammals, Acute	Toxicity, Special	Toxicity, Birds	Toxicity, Fish	Toxicity, Invert.	Persistence	Biomagnification	Environ. Mobility	Wide Spectrum Activity	Regulation Discussed	Likely to be Cancelled Soon	"Wasteful" Use Pattern	No Available Alternatives	Increased Use Forecast	Decreased Use Forecast	A Leading Product in an Important Group	Group Already Well Represented	Special Consideration	Total	Rank, This Category
	+7	+4	+3	+2	+1	-1	+3	+4	+1	+1	+1	+4	+2	+1	+1	+3	-3	+3	+3	+4	-4	+6	-5	±3		
Toxaphene	5	0	3	0	1	-1	2	0	0	1	0	2	1	0	1	1	0	1	1	3	0	5	0	0	26	2
DDT	4	0	1	0	0	-1	2	0	1	1	0	4	2	1	1	3	-3	2	1	0	-4	2	0	-3	14	
Chlordane	3	3	2	1	1	-1	1	0	0	1	0	4	2	1	1	2	0	2	2	2	0	3	0	0	30	1
Aldrin	2	2	3	0	1	0	2	0	1	1	0	4	2	1	1	3	-3	3	1	0	-3	4	0	0	23	3
Methoxychlor	2	2	1	2	1	0	0	0	0	1	0	1	1	0	1	0	0	0	0	2	0	1	-3	0	12	
Heptachlor	2	1	3	0	0	0	2	0	0	1	0	4	2	1	1	2	0	0	0	0	0	0	-3	0	16	
Dicofol	1	0	1	0	1	0	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	-3	0	4	
Endrin	1	1	2	1	0	0	3	0	1	1	0	3	2	1	1	0	-2	0	0	0	0	0	-5	0	10	
Endosulfan	1	0	2	0	0	0	2	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0	-5	0	5	
Chlorobenzilate	1	0	2	0	0	0	1	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	-3	0	5	
Lindane and BHC	1	1	2	0	1	-1	2	0	0	1	0	4	2	1	1	3	0	0	0	0	0	2	-3	0	15	
DDD	0	0	2	0	0	0	0	0	0	1	0	4	2	1	1	3	-2	0	0	0	0	0	-5	0	7	
Dieldrin	0	4	0	0	0	0	2	0	1	1	0	4	2	1	1	3	-3	0	1	0	-1	0	-4	0	12	
Carbaryl	5	1	3	2	1	-1	1	0	0	0	0	0	0	0	1	2	0	0	0	2	0	7	0	0	24	6
Carbofuran	2	0	3	0	0	-1	3	0	1	1	0	0	0	0	1	0	0	0	0	4	0	6	0	0	20	8
Metalkamate	2	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	0	13	
Methomyl	1	0	3				3	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	11	
Aldicarb	1	0	3	0	0	0	3	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	-1	-1	9	
Zectran	1	1	0	1	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	-3	0	5	
Methyl Parathion	4	0	3	0	0	-1	3	0	1	0	1	0	0	0	1	1	0	0	1	4	0	6	0	1	25	4
Malathion	4	3	2	2	1	-1	1	0	0	1	0	0	0	0	1	0	0	0	3	3	0	5	0	0	25	5
Parathion	3	0	3	0	0	-1	3	0	1	1	1	0	0	0	1	1	-1	0	0	1	0	2	0	2	18	10
Diazinon	2	4	2	2	1	0	2	0	1	1	0	1	0	0	1	0	0	0	0	1	0	2	0	0	20	9
Disulfoton	2	0	3	0	1	0	3	0	1	1	0	1	0	0	0	0	0	0	0	1	0	5	0	2	20	7
Phorate	2	0	3	0	0	0	3	0	1	1	0	1	0	0	0	0	0	0	0	0	0	2	-2	0	11	
Monocrotophos	2	0	3	0	0	-1	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	5	
Chlopyrifos	2	2	0	2	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	-2	0	10	
Azinphos-methyl	1	0	3	0	1	0	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	-3	0	7	
Fensulfothion	1	0	3	0	0	0	3	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	-3	0	8	
Dyfonate-	1	0	2	0	0	0	3	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	-5	0	4	
Ethion	1	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	1	
Ronnel	1	2	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	4	
Carbophenthion	1	0	3	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	4	
Naled	1	1	1	1	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	3	
Dimethoate	1	1	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	2	
Abate	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	-3	0	1	
Dichlorvos (DDVP)	1	4	0	1	1	0	2	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	-2	0	10	
Dicrotophos	1	0	2	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-5	0	1	
Prolate	1	0	3	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	7	
Inorganic Arsenates	2	0	3	0	0	0	2	0	0	0	0	4	1	1	0	2	0	0	0	0	-1	4	0	0	18	10

TABLE A-I (Continued)

Part B - Herbicides

Characteristic / Rating Scale / Pesticide	Production and Use						Environmental Concern									Regulatory Interest				Other Criteria						
	Production or Import, Total	Ind., Comm., and Inst. Use	Agricultural Use	Governmental Use	Home and Garden Use	Export and Other Use	Toxicity, Mammals, Acute	Toxicity, Special	Toxicity, Birds	Toxicity, Fish	Toxicity, Invert.	Persistence	Biomagnification	Environ. Mobility	Wide Spectrum Activity	Regulation Discussed	Likely to be Cancelled Soon	"Wasteful" Use Pattern	No Available Alternatives	Increased Use Forecast	Decreased Use Forecast	A Leading Product in an Important Group	Group Already Well Represented	Special Consideration	Total	Rank, this Category
	+7	+4	+3	+2	+1	-1	+3	+4	+1	+1	+1	+4	+2	+1	+1	+3	-3	+3	+3	+4	-4	+8	-5	±5		
Atrazine	6	1	3	0	1	0	0	0	0	0	0	2	0	1	0	0	0	0	2	2	0	8	0	0	26	1
Simazine	2	4	1	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	4	0	0	15	10
Propazine	1	0	3	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	0	0	10	
Propachlor	3	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	0	13	
Alachlor	3	0	3	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	4	0	6	0	0	18	5
CDAA	2	0	3	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	8	
Propanil	2	0	2	0	0	-1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	5	
Diphenamid	1	0	2	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	-2	0	5	
Maleic Hydrazide	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	6	
2,4-D	4	1	3	2	1	-1	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	8	0	0	22	2
2,4,5-T	2	1	2	0	0	-1	2	2	0	0	0	1	0	0	0	3	-1	0	0	0	-2	4	0	-2	11	
Silvex	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	7	
Chloramben	3	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0	0	13	
Dicamba	1	2	2	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	3	0	3	0	0	15	9
2,3,6-TBA	1	2	0	0	0	0	1	0	0	0	0	2	0	0	0	2	0	0	0	0	-2	0	0	0	6	
DCPA	1	0	2	0	1	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	1	0	0	8	
Endothall	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
Picloram	1	2	1	0	0	-1	0	0	0	0	0	4	0	0	0	1	0	0	0	1	0	0	0	0	9	
Trifluralin	3	0	3	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	3	0	8	0	0	20	4
Dinoseb	1	1	2	1	0	0	3	0	1	1	0	1	0	0	0	0	0	0	0	0	0	2	0	0	13	
Nitralin	1	0	3	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	2	0	0	8	
MSMA	3	1	2	0	0	0	1	0	0	0	0	3	1	0	1	3	0	0	0	0	-1	8	0	0	21	3
DSMA	2	0	1	0	0	0	1	0	0	0	0	3	1	0	1	3	0	0	0	0	-1	0	-3	0	8	
Cacodylic Acid	1	1	1	0	0	0	1	0	0	0	0	3	1	0	0	3	0	0	0	0	-3	0	-3	0	5	
Bromacil	2	4	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	6	0	0	16	7
Diuron	2	3	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	7	0	0	16	8
Fluometuron	1	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	
Linuron	1	2	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	7	
Norea	1	1	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	
Butylate	2	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5	0	0	10	
EPTC	2	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	5	0	0	12	
Vernolate	1	0	2	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	
Chorpropham	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-1	0	0	0	3	
Naptalam	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	
TCA	2	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0	0	13	
Dalapon	1	0	0	2	0	-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5	0	0	8	
DEF	2	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	10	
Merphos	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	8	
Chlorate-Borate	4	3	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	-1	8	0	0	18	6
Ammonium Sulfamate	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	8	
Sodium Arsenite	1	1	1	0	0	0	3	0	0	0	0	3	1	0	0	0	0	0	0	0	-1	0	0	0	9	

TABLE A-I (Continued)

Part C - Fungicides and Wood Preservatives

	Production and Use						Environmental Concern									Regulatory Interest				Other Criteria						
Characteristic	Production or Import, Total	Ind., Comm., and Inst. Use	Agricultural Use	Governmental Use	Home and Garden Use	Export and Other Use	Toxicity, Mammals, Acute	Toxicity, Special	Toxicity, Birds	Toxicity, Fish	Toxicity, Invert.	Persistence	Biomagnification	Environ. Mobility	Wide Spectrum Activity	Regulation Discussed	Likely to be Cancelled Soon	"Wasteful" Use Pattern	No Available Alternatives	Increased Use Forecast	Decreased Use Forecast	A Leading Product in an Important Group	Group Already Well Represented	Special Consideration	Total	Rank, this category
Rating Scale	+7	+4	+3	+2	+1	-1	+3	+4	+1	+1	+1	+4	+2	+1	+1	+3	-3	+3	+3	+4	-4	+8	-5	±5		
Pesticide																										
Creosote	7	4	1	1	0	0	1	4	0	1	1	2	1	0	1	0	0	1	3	0	0	8	0	1	37	1
Coal Tars	6	4	0	0	0	0	1	4	0	0	0	2	0	0	0	1	0	1	2	0	0	4	-5	0	20	7
Petroleum Oils	6	3	2	0	0	0	[illegible]	0	0	1	0	2	0	0	1	0	0	1	2	0	0	2	-3	0	17	10
Inorganic Sulfur	6	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	15	
Inorganic Coppers	4	2	2	1	0	0	2	0	0	1	0	2	0	1	0	0	0	0	0	0	0	8	0	0	21	5
Organo Coppers	1	3	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-3	0	5	
Organo Tins	1	3	2	0	0	0	2	0	0	1	1	3	2	0	0	0	0	0	0	1	0	4	0	0	20	6
Mercurials	0	3	0	0	1	0	3	0	1	1	1	4	2	1	1	3	-3	0	0	0	-3	4	0	-2	17	10
Chromates	2	4	0	0	0	0	2	1	0	0	0	3	0	0	0	0	0	0	0	1	0	4	0	0	17	10
Pentachlorophenol	5	4	0	0	1	0	2	4	0	0	1	3	0	0	0	0	0	0	3	1	0	8	0	0	32	2
Trichlorophenol	3	4	0	0	0	0	1	3	0	0	0	2	0	0	0	0	0	0	1	1	0	4	0	0	19	8
Pentachloronitro Benzene	1	2	2	0	0	0	1	1	0	0	0	1	0	0	0	2	0	0	1	0	0	2	0	0	13	
Captan	3	0	3	0	1	0	0	2	0	0	0	0	0	0	0	2	0	0	1	2	0	8	0	0	22	3
Captafol	1	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	10	
Folpet	1	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	8	
Maneb	2	0	3	0	1	-1	0	4	0	0	0	1	0	0	0	3	0	0	0	1	0	8	0	0	22	4
Metham	2	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	10	
Zineb	1	0	3	0	1	-1	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	12	
Ziram	1	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	
Ferbam	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Nabam	1	0	1	0	1	0	2	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	11	
Niacide[3]	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Polyram	1	0	2	0	0	0	0	4	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0		10	
Thiram	1	1	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	10	
PETD	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Dodine	1	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0	12	
Benomyl	2	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0	12	
Dinocap	0	0	2	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	7	

TABLE A-1 (Concluded)

Part D - Fumigants

Characteristic / Rating Scale / Pesticide	Production and Use					Environmental Concern									Regulatory Interest				Other Criteria						
	Production or Import, Total +7	Ind., Comm., and Inst. Use +4	Agricultural Use +3	Governmental Use +2	Home and Garden Use +1	Export and Other Use -1	Toxicity, Mammals, Acute +3	Toxicity, Special +4	Toxicity, Birds +1	Toxicity, Fish +1	Toxicity, Invert. +1	Persistence +4	Biomagnification +2	Environ. Mobility +1	Wide Spectrum Activity +1	Regulation Discussed +3	Likely to be Cancelled Soon -3	"Wasteful" Use Pattern +3	No Available Alternatives +3	Increased Use Forecast +4	Decreased Use Forecast -4	A Leading Product in an Important Group +8	Group Already Well Represented -5	Special Consideration ±5	Total	Rank, This Category
Dichlorobenzene	5	3	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	5	0	+1	21	1
Methyl Bromide	3	2	2	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	1	0	8	0	0	20	2
Dichloropropene Propane	3	0	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	13	4
Ethylene Dibromide	3	3	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	14	3
Dibromochloropropane	2	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7	
Carbon Disulfide- Tetrachloride	2	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
Ethylene Dichloride	2	2	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-3	0	4	
Dichloronitroethane	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
Naphthalene	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
Ethylene Oxide- Carbon Dioxide	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Aluminum Phosphide	0	4	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	12	5
Calcium Cyanide	0	1	1	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	-1	0	0	0	5	
Sulfuryl Fluoride	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	6	

GUIDELINES FOR RATING PESTICIDES IN TABLE A-I

Production Rating Scale

Production (mm lb/year AI)	Rating
< 1	0
1-4	+1
5-14	+2
15-29	+3
30-49	+4
50-99	+5
100-200	+6
> 200	+7

Toxicity, Acute LD_{50}	Rating
> 2,000	0
500-2,000	1
50-500	2
< 50	3

Toxicity, Special

Carcinogenic, teratogenic or mutagenic properties of the pesticide or its impurities reported.

Toxicity

Toxicity to birds, fish or invertebrates resulting from normal use patterns.

Persistence

The following scale has been used where possible, but persistence varies with conditions and data are often unavailable.

Time (months for 75-100%) Disappearance	Rating
< 1	0
1-3	1
3-10	2
10-18	3
> 18	4

Biomagnification, wide spectrum activity and the categories under regulatory interest are largely self-explanatory. The "no alternatives available" implies that no effective, economical substitute pest-control method is now available for one or more major uses of the named pesticide.

The "increased" and "decreased use forecast" columns consider restrictions on competitive products and regulatory actions as well as normal market potential.

The column, "A leading product in an important group," considers not only the chemical class but also the use pattern. The highest rating is given to a product that is a leading example of an important group in which no single member is otherwise highly rated.

Special Considerations

DDT: The decision to cancel most uses of DDT in the U.S. has already been made by EPA in a special ruling.

Aldicarb: Pure aldicarb is the most toxic of major pesticides, but is marketed only as a 10% granular formulation.

Methyl parathion: The substitution of methyl parathion for the less toxic DDT on cotton has necessitated a farm worker retraining program.

Disulfoton: This product is especially representative of a large class of very toxic agricultural insecticides.

Parathion: The reentry controversy requires special consideration.

2,4,5-T: The production of 2,4,5-T has dropped greatly since its military use halted and in addition, presently produced material contains little or none of the objectionable chloro-dioxins formerly produced as an impurity.

Creosote: The environmental aspects of this heavily used pesticide have been little studied. Much creosote-treated wood is placed in close contact with water.

Mercurials: The objectionable use of alkyl mercury fungicides for seed treatment has been cancelled.

Dichlorobenzene: Much of this chlorinated hydrocarbon is placed directly into wastewater via lavatory use* and into the air we breathe at home and at work. Studies of the environmental aspects are negligible to date, and the conventional method used for analysis of chlorinated hydrocarbon pesticides in water does not normally detect dichlorobenzene. It has, however, been detected in the blood of workers exposed to it regularly and appears to accumulate in fatty tissues like other chlorinated hydrocarbons.

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* A fundamental question of the definition of the word pesticide is raised when one considers the lavatory use of dichlorobenzene (e.g., does it kill organisms that cause odors?). Disinfectants are increasingly listed with pesticides in some government statistics.

TABLE A-II

SUMMARY OF RATINGS

Group Rank	Insecticides	Total	Herbicides	Total	Fungicides and Preservatives	Total	Fumigants	Total
1	Chlordane	30	Atrazine	26	Creosote	37	Dichlorobenzene	21
2	Toxaphene	26	2,4-D	22	PCP	32	Methyl Bromide	20
3	Aldrin	25	MSMA	21	Captan	22	Ethylene Dibromide	14
4	Methyl Parathion	25	Trifluralin	20	Maneb	22	Dichloropropene-propane	13
5	Malathion	25	Alachlor	18	Inorganic Coppers	21	Aluminum Phosphide	12
6	Carbaryl	24	Chlorates	18	Organo Tins	20		
7	Disulfoton	20	Bromacil	16	Coal Tars	20		
8	Carbofuran	20	Diuron	16	TCP	19		
9	Diazinon	20	Dicamba	15	Chromates, Petroleum Oils, Mercurials (Tie)	17		
10	Inorganic Arsenates Parathion (Tie)	18	Simazine	15				

TABLE A-III

PESTICIDES RECOMMENDED FOR STUDY

	Pesticide	Rating Total	Type
1	Creosote	37	F
2	Pentachlorophenol	32	F
3	Chlordane	30	I
4	Toxaphene	26	I
5	Atrazine	26	H
6	Aldrin	25	I
7	Methyl Parathion	25	I
8	Malathion	25	I
9	2,4-D	24	H
10	Carbaryl	24	I
11	Captan	22	F
12	Maneb	22	F
13	MSMA	21	H
14	Dichlorobenzene	21	Fu
15	Methyl Bromide	20	Fu
16	Trifluralin	20	H
17	Diazinon	20	I
18	Disulfoton	20	I
19	Carbofuran	20	I
20	Parathion	18	I
21	Alachlor	18	H
22	Chlorates	18	H
23	Bromacil	16	H
24	Diuron	16	H
25	Copper or organotin compounds	(21)a/	F

I - Insecticide; H - Herbicide; F - Fungicide; Fu - Fumigant.

a/ The copper (and similarly the tin, chromium and mercury) fungicides require special consideration because no single chemical compound is involved.

APPENDIX B

PESTICIDE USAGE IN SELECTED STATES

Data on the statewide use of pesticides is now being compiled by several states. As a result of our survey of the Federal/State Cooperative Extension Services (discussed in Chapter IV, Section C-2), data from several states were obtained. The data vary widely in quantity and quality. For a few states the data appear to include most--although not all--of the pesticide quantities used within the state. For other states, data may be available on only a few pesticides (e.g., restricted chlorinated hydrocarbons), for only a few counties within the state, or in a form which does not denote the total pounds of active ingredient for individual pesticides.

One of the most comprehensive reports is available from California. The California Department of Agriculture compiles information on pesticide use from data submitted by: "Licensed Agricultural Pest Control Operators, Licensed Structural Pest Control Operators, California Division of Highways, California Department of Water Resources, Vector Control Agencies, State and County Agricultural Departments, University of California, County Road Departments, Irrigated Districts, U.S. Government Agencies, Reclamation Districts, City and County Parks, and various School Districts. It also includes reports from growers using injurious materials and injurious herbicides requiring a permit for use." The report does not identify pesticides that require the permit for use noted in the last sentence; presumably most agricultural pesticides are included, but pesticides used in the home and garden may not be.

TABLE B-I

PESTICIDE USAGE IN ARIZONA, 1972[96]

Pesticide	Quantity (1,000 lb AI)
A. INSECTICIDES	
Chlorinated Hydrocarbons	
Aldrin	27.8
BHC	9.2
Chlordane	135.5
Chlorobenzilate	1.0
DDT	0.0[a]
Dieldrin	29.4
Dilan®	0.0[a]
Endrin	23.7
Heptachlor	12.0
Kelthane (Dicofal)	5.2
Perthane®	50.6
Rhothane® (DDD)	0.0[a]
Strobane®	509.2
Thiodan® (Endosulfan)	77.0
Toxaphene	1,468.3
Others	1.1
Subtotal	2,350.0
Organic Phosphates	
Azodrin®	197.1
Bidrin®	12.7
Cygon® (Dimethoate)	47.2
Delnav® (Dioxathion)	14.6
Diazinon	75.6
Dibrom® (Naled)	13.7
Disyston® (Disulfoton)	81.1
Dylox® (Trichlorfon)	16.1
Ethion	11.9
Guthion® (Azinphosmethyl)	18.5
Malathion	79.0
Meta Systox R (Oxydemeton--methyl)	5.0
Monitor®	48.9
Parathion (Ethyl)	1,231.5
Parathion (Methyl)	2,052.4
Phosdrin® (Mevinphos)	116.9
Phosphamidon	21.0
Systox® (Demeton)	0.7
Thimet® (Phorate)	102.6
Subtotal	4,146.5
Carbamates	
Baygon®	0.5
Lannate® (Methomyl)	122.9
Sevin® (Carbaryl)	232.2
Temik® (Aldicarb)	41.5
Subtotal	397.1
Miscellaneous Insecticides	
Cryolite	120.9
Thuricide®	77.0 gal.
Sabadilla	24.3 gal.
Ryania	11.0
Sulfur	1,148.6
Galecron® (Chlordimeform)	160.9
Subtotal	1,441.4[b]
Fumigants	
Methyl Bromide	6.9
Vapam® (Metham)	21.8
Nemagon® (DBCP)	191.5
Telone (D-D®)	632.6
D-D® (Vidden-D)	165.0
Subtotal	1,017.8
Total Insecticides	9,352.8[b]

TABLE B-I (Concluded)

Pesticide	Quantity (1,000 lb AI)
B. HERBICIDES	
2,4-D	16.8
2,4,5-T	16.2
MCPA	4.2
Banvel-D® (Tricamba)	6.9
Fenac®	0.0[a]
Endothall	8.9
Dacthal® (DCPA)	70.8
Dinoseb (DNBP)	88.0
Dalapon	45.9
TCA	13.1
Balan®	25.5
Planavin® (Nitralin)	0.7
Treflan® (Trifluralin)	98.0
Bensulide	24.8
Eptam® (EPTC)	14.6
IPC (Propham)	7.7
Aminotriazole (Amitrole)	0.6
Atrazine	15.3
Caparol (Prometryne)	73.5
Diquat®	0.4
Paraquat	22.2
Prometone	3.4
Pyramin® (Pyrazon)	0.0[a]
Propazine	0.5
Simazine	13.0
Cotoran® (Fluometuron)	0.0[a]
Hyvar X® (Bromacil)	4.6
Monuron	8.1
Diuron	52.3
Linuron	4.6
Tenoran® (Chloroxuron)	0.0[a]
DSMA	61.0
MSMA	112.6
DMAA	24.0
Total	838.2

Pesticide	Quantity (1,000 lb AI)
C. DEFOLIANTS AND DESSICANTS	
Def®	75.5
Folex®	10.8
Sodium Chlorate	1,145.4
Magnesium Chloride	16.5
Dessicant L-10® (Arsenic Acid)	63.7
Total	1,311.9
D. FUNGICIDES	
Captan	7.0
Copper Sulfate	40.0
Botan® (DCNA)	5.4
Benlate (Benomyl)	4.8
Folpet	0.0[a]
Daconil® (Chlorothalonil)	3.6
Maneb	36.0
PCNB	12.6
Polyram®	0.0[a]
Zineb	33.5
Ziram	0.0[a]
Phaltan (Folpet)	0.9
Total	143.8

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a/ Use reported during 1966 to 1971 period.

b/ Total does not include Thuricide® (*Bacillus thuringiensis*) and Sabadilla.

TABLE B-II

PESTICIDE USAGE IN CALIFORNIA--QUANTITIES REPORTED FOR 1972[97]

PART A: INSECTICIDES Total: 28,622,130 lb AI
(includes Rodenticides, Miticides, Molluscides, and Insect Repellents)

Pesticide	Quantity (lb AI)
Methyl bromide	5,368,100
Dichloropropene (and related compounds)	4,720,400
Chloropicrin	1,873,800
Toxaphene	1,783,700
Carbon disulfide	1,757,800
Parathion	1,097,100
Malathion	922,000
Endosulfan	882,600
Carbaryl	845,600
Methyl parathion	768,600
DBCP	625,100
Chlordane	592,500
Dicofol	588,300
1,1,2-Trichloroethane	489,100
Naled	463,500
Methomyl	456,000
Azinphosmethyl	436,400
Cryolite	370,400
Mevinphos (and related compounds)	353,300
Dimethoate	345,200
Omite	313,500
Diazinon	311,200
Ethion	220,600
Trichlorfon	215,500
Disulfoton	211,200
Azodrin	205,800
Chlorphenamidine	189,400
Sulfuryl fluoride	177,800
Aldicarb	164,500
Methyl-demeton	149,300
Methoxychlor	140,100
Imidan	116,100
Carbophenothion	112,300
TEPP (and related compounds)	111,100
Dioxathion (and related compounds)	107,400
Lead arsenate	106,800
EDB	90,100
Dieldrin (and related compounds)	81,700
DDT	80,800
Monitor	78,400
Perthane (and related compounds)	67,900
Phosphamidon (and related compounds)	65,500
Chlorobenzilate	64,000
Fenthion	57,800
Carzol SP	42,800
Aluminum phosphide	42,200
Demeton	37,900
Aldrin	32,300
Phosphoric acid	26,700
Calcium arsenate	22,000
Gardona	21,400
Sodium arsenate	19,200
Bidrin	17,300
Carbon tetrachloride	17,300
Morestan	16,200
Baygon	12,800
Lindane	11,800
Chlorpyrifos	11,200
Carbofuran	10,600
Endrin treated seed	8,000
Dichlorvos	7,800
EPN	7,200
Tetradifon	7,100
Metaldehyde	6,100
Abate	5,900
Rotenone (and related compounds)	5,800
Ethylene dichloride	4,400
Heptachlor	3,700
Silica aerogel	3,500
Cube extracts, other	3,100
Pine oil	3,100
Sodium fluoride	2,900
Arsenic trioxide	2,800
BHC (and related compounds)	2,400
MGK R-11	2,200
Zinc phosphide	2,100
Zectran	2,000
Lethane 384-R	1,700
Sodium hyposulfite	1,400
Endrin	1,350
Gophacide	1,300
Pyrethrins	1,300
Azinphosmethyl	1,200
Tritox X114 (trichloroacetonitrile)	1,200
Aramite	1,100
Ethyl hexanediol	1,100
Methidathion	1,100
Strychnine	1,000
Binapacryl	900
Butoxy polypropylene glycol	900
Mixed rosins and fatty acids	900
Sabadilla alkaloids	900
Ethylene oxide adduct nonylphenol	800
Methylated naphthalenes	500
Dyfonate	430

TABLE B-II (Continued)

Pesticide	Quantity (lb AI)
Calcium cyanide	300
Phosphorus	300
Plictran	300
Sodium fluoroacetate	300
Fensulfothion	250
Ryania speciosa	250
Methyl trithion	200
Pentac	200
1,1,1-Trichloroethane	200
Ronnel	170
Diphacinone	150
Ammonium fluosilicate	130
Ethyl formate	100
Sulfur dioxide	100

PART B: HERBICIDES Total: 16,090,710 lb AI
(includes Plant Growth Retardants)

Pesticide	Quantity (lb AI)
Sodium chlorate	6,237,300
Sulfuric acid	1,291,900
2,4-D	1,219,400
Sodium arsenite	716,100
Molinate	657,600
Def®	469,700
Dinoseb and salts	460,600
Simazine	358,300
Dalapon	335,900
DCPA	281,500
MCPA (and related compounds)	260,[illegible]00
MSMA	245,800
Paraquat	235,600
Diuron	228,000
Propham	206,300
Trifluralin	198,500
TCA, Sodium salt	196,[illegible]00
Nitrofen	163,400
Diphenamid	162,500
Atrazine	152,600
Bromacil	152,200
Magnesium chloride	149,700
Amitrole	141,600
Propanil	140,000
Sodium metaborate	132,200
AMS	120,600
Folex	109,400
2,4,5-T	107,900
Maleic hydrazide	86,300
EPTC	67,100
Pebulate	61,300
DSMA	58,700
Pyrazon (and related compounds)	48,400
Benefin	47,800
Prometryne	40,200
Nitralin	38,900
Dichlorprop (and related compounds)	33,900
Endothall	33,300
Monuron	33,300
Silvex (and related compounds)	32,500
Karbutilate	29,300
Fluometuron	25,100
Dicamba	21,800
Cacodylic acid	20,900
4(2,4-DB) (and related compounds)	20,200
Butylate	18,200
Bromoxynil	17,200
Linuron	17,200
Phenmedipham	16,000
Chloropropham	14,800
Sodium cacodylate	14,500
Bensulide	12,900
Diquat	12,900
Fenac	12,200
Chloroxuron	11,900
Cycloate	11,400
(2,4-DB)	8,900
Magnesium chlorate	8,900
Norea (and related compounds)	8,500
Calcium cyanamide	8,400
2,3,6-TBA dimethylamine salt (and related compounds)	7,200
Picloram (and related compounds)	6,100
Chlorine	5,300
Dichlobenil	5,100
Gibberellic acid	4,800
Propachlor	4,800
Barban	4,500
Isopropalin	4,000
Alachlor	4,000
MPMT	2,900
Ethephon	2,700
Naptalam	2,500
CDEC	1,600
Naphthalene acetic acid (and salts)	1,600
Bladex®	1,400
MCPP (and salts)	1,200
Igran®	900
MCPB, sodium salt	800
Propazine	800
Monuron-TCA	500
Terbacil	500
Triallate	500
Kerb®	400
Acrolein	300
Cypromid	300
Ferrous sulfate	300
Prometone	300
CMA	200
Succinic acid 2,2-dimethyl hydrazide	200
MCPPA	160
Terbutol	140
Ammonia	110
Chloramben	100

TABLE B-II (Continued)

PART C: FUNGICIDES AND WOOD PRESERVATIVES

Total: 2,964,960 lb AI

Pesticide	Quantity (lb AI)
Copper	592,800
Copper sulfate/pentahydrate	506,100
Difolatan	283,200
Dithane M-45®	264,400
Isopropyl alcohol	216,200
Lime sulfur	161,300
Maneb	161,100
Captan	115,100
Zineb	112,600
Copper sulfate	95,700
Copper oxychloride sulfate	85,200
PCNB	53,700
Zinc sulphate	46,000
DCNA	21,000
Dyrene	20,400
Chloroneb	19,900
Polyram	19,200
Copper naphthenate	18,900
Thiram	18,500
Ferbam	18,300
Nabam	16,300
Benomyl®	15,000
Sodium polysulfide	14,700
BTB[a]	12,300
Ziram	12,300
PCP	7,900
Dexon	7,400
Biphenyl	6,900
Terrazole®	6,900
Chlorothalonil	6,800
2-chloro-4-phenylphenol	5,200
Copper-zinc sulfate complex	3,700
Roccal®	3,100
Glyodin	3,000
Dichlone	2,900
Karathane®	2,400
Metham	1,300
Folpet	1,100
Copper dihydrazinium sulfate	1,000
Dodine	850
Streptomycin	800
Benzalkonium chloride	500
Copper linoleate	500
Orthophenylphenol	400
2-Aminobutane	400
Copper oleate	300
Streptomycin sulfate	300
Triphenyltin hydroxide	280
Nabac	200
Beta-naphthol	190
Cadmium succinate	170
Calomel	150
Ortho benzylparachlorophenol	120

PART D: MISCELLANEOUS

Total: 107,938,490 lb AI

Pesticide	Quantity (lb AI)
Petroleum hydrocarbons	27,924,800
Petroleum oil unclassified	19,119,300
Sulfur	16,591,000
Mercury treated seed--not included in state or county totals	16,584,200
Petroleum oil unclassified	7,963,900
Aromatic petroleum solvents	7,540,200
Calcium hydroxide	4,379,600
Mineral oil	3,225,500
Xylene (and related compounds)	1,271,700
Borax	1,165,000
Petroleum distillates	490,500
Alkylarylpolyoxyethylene	408,300
Free fatty acids and/or amine salts	213,500
Copper hydroxide	144,900
Alkylarylpolyoxyethylene ether	140,300
Alkylarylpolyoxy glycol	79,200
Dialkylbenzene dicarboxylate	76,700
Glycol ethers	75,100
Propylene glycol	51,100
Bentonite	38,200
Casein	31,100
Alkylarylpolyether alcohol	30,800
Phthalic glycerol alkyd	29,500
Arsenic acid	28,100
Sodium sulforicinoleate	22,300
Isooctylphenoxypolyethoxyethanol	21,100
Alkyl (C 10-C 18)- omega hydroxypoly (oxethylene) sulfate	20,900
Polyethylene glycol, dodecyl ester	20,600
Copper salts of fatty and rosin acids	18,900
Calcium carbonate	15,500
Potassium oleate	15,400
Poly-1-p-menthene	12,900
Alkylpolyoxyethylene ether	10,500
Zinc	10,200
Dulcite	9,300
Trimethyl nonanolethylene oxide complex	8,200
Dibasic ammonium phosphate	8,000
Chlorobenzene	7,000
Mixed amide-amine oleate fatty acids and polyamines	6,600
Dichloro-s-triazinetrione	6,500
Cadmium sebacate	6,000
Piperonyl butoxide, tech.	5,900
Alkylarylpolyoxyethylene ethanol	5,800
Alkylaryl sulfonates	5,700
Diglycerides of fatty acids	5,700
Alkylolecin aromatic polymers	5,300
Potassium abietate	4,700
1,3-Propane diol	4,400
Citric acid	4,200
Sec-butylphenoxypolypropylene oxypolyethylenoxyethanol	4,000

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[a] It is believed BTB should be BTC, a fungicide.

TABLE B-II (Concluded)

Pesticide	Quantity (lb AI)
Sodium nitrate	
Sodium sulfonates	3,300
Coconut diethanolamide	3,800
Hexahydric alcohol	3,000
Phosphoproteins	2,900
Alkylbenzene sulfonic acid	2,800
Alkyphenoxypolyethoxy ethanol	2,800
Sodium dioctylsulfosuccinate	2,700
Lactose	2,500
2-Propene-1,1-dioldiacetate	2,500
Sodium hypochlorite	2,300
Alkylpolyglycol ether	2,200
Triethylene glycol	2,200
Triethvlene glycol	2,200
Alkylphenylpolyethoxy ethanol	2,100
Trimethylnonyl ether of polyethylene glycol	2,100
Nonionic surfactant	2,000
Iron	1,900
Chlor-flurenol	1,800
Sodium salt of oleic, linoleic, and resin acids	1,800
Ethyl alcohol	1,700
Carbon	1,600
2-Butoxyethanol	1,500
EDTA-tetrasodium salt	1,500
Manganese sulfate	1,500
Vegetable oil	1,300
Octylphenoxypolyethoxy ethanol	900
Sodium sulfate diethylene glycol abietate	900
Benzoyl chloride hydrazone	800
Nonylphenol ethylene oxide adduct	800
Coconut diethanolamide	700
A-/p-nonylphenyl/-omegahydroxypoly/oxyethylene	600
Calcium salts of casein and soy	600
Sorbitol	600
Aluminum sulfate	500
Soap	500
Synthetic vinyl resin	500
Triethanolamine salt of alkyl sulfonate	500
Polymethylene-p-nonylphenylpolyoxyethylene propanol	450
Amino acids and amino salts	400
2-P-cymenol, chloroethyl ester	400
Ferric sulfate	400
Methyl-9-hydroxyfluorene-9-carboxylate	400
Trisodium phosphate	400
Methyl-2,3-dichloro-9-hydroxyfluorene-9-carboxylate	300
Molybdenum	300
N-octylbicycloheptanedicarboximide	300
Potassium lysalbinate	300
Sawdust	300
Lauric diethanolamine condensate	200
Manganese	200
Oleic acid	200
Phosphorus pentoxide	200
Potassium laurate	200
Potassium myristate	200
Alpha(p-nonyl phenyl)-omega-hydroxy-poly (oxyethylene) sulfate	170
Alkylamine acetate	150
Alkylpolyethylene glycol ether	150
Polyhydric alcohol	150
Morpholine ester of abietic and oleic acids	140
Terpineols	140
Modified phthalic glycerol alkyd resin	120
Dried blood	110
Hydroxyethyl cellulose	110
Ammonium caseinate	100

TABLE B-III

REPORT OF PERSISTENT PESTICIDES SOLD IN FLORIDA, 6 APRIL - 31 DECEMBER 1972[98]

Pesticide	Quantity AI Sold	
	As Solid, Pounds	As Liquid, Gallons
Aldrin	247,129	106,281
Arsenic and Its Compounds	533,425	--
BHC	27,285	1.25
Chlordane	909,549	59.63
DDD (TDE)	5,070	--
DDT	78,902	--
Dieldrin	21,019	2,592
Endrin	17,985	--
Heptachlor	122,580	--
Lindane	14,676	1
Mercury and Its Compounds	6,031	--
Mirex	504	--

TABLE B-IV

ESTIMATED PESTICIDE CONSUMPTION IN THE STRUCTURAL PEST CONTROL INDUSTRY IN HAWAII, 1972[a]

Pesticide	Quantity (1,000 lb AI)
Aldrin	100.0
Baygon®	8.0
Chlordane	125.0
Chlorpyrifos	5.0
Diazinon	7.0
Dichlorvos	6.0
Dieldrin	16.0
Heptachlor	13.5
Malathion	4.0
Pentachlorophenol	15.0
Pyrenone®	3.0
Sulfuryl Fluoride	158.6
Miscellaneous	13.0
TOTAL:	474.1

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a/ Data adapted from Ref. 99.

TABLE B-V

PESTICIDE USAGE FOR CROPS
CANYON COUNTY, IDAHO-1972[a]

A. INSECTICIDES

Pesticide	Quantity (1000 lb AI)
Aldicarb	1.1
Azinphosmethyl	0.8
Bacillus Thuringiensis	0.4
Carbophenothion	2.8
Chlordimeform	10.4
DDT	4.9
Demeton	12.9
Diazinon	8.7
Dicofol	5.9
Dimethoate	2.4
Disulfoton	17.3
DNOC	24.7
Dyfonate®	6.4
Endosulfan	17.9
Ethion	0.3
Imidan®	1.1
Malathion	20.9
Methomyl	3.2
Methyl Parathion	18.3
Mevinphos	0.2
Naled	12.1
Oxydemeton-methyl	5.8
Parathion	11.5
Perthane®	0.5
Proparagite	3.3
TEPP	3.0
Toxaphene	4.7
Trichlorfon	49.5
Total Insecticides	251.0

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[a] Data adapted from Ref. 100.

TABLE B-V (Concluded)

B. HERBICIDES

Pesticide	Quantity (1000 lb AI)
Alachlor	7.2
Atrazine	28.6
Benefin	2.6
Bromoxynil	1.4
Chloroxuron	3.1
Chlorpropham	60.0
Cycloate	126.0
2,4,-D	36.3
2,4,-DB	6.0
DCPA	95.1
Dicamba	0.1
Diquat®	3.0
EPTC	5.4
Linuron	1.1
Nitralin	1.0
Nitrofen	1.0
Pebulate	7.0
Phenmedipham	1.2
Propachlor	20.6
Pyrazon	14.0
Simazine	4.0
Terbacil	4.8
Trifluralin	28.6
Total Herbicides	458.1

C. FUNGICIDES

Pesticide	Quantity (1000 lb AI)
Dithane®	58.2
Maneb	2.1
Polyram®	1.5
Sulfur	5.0
Triphenyltim hydroxide	3.2
Zineb	6.2
Total Fungicides:	76.2

TABLE B-VI

AGRICULTURAL PESTICIDE USAGE IN ILLINOIS, 1972[a]

A. INSECTICIDES

Pesticide	Quantity (1000 lb AI)
Aldrin	2,260.0
Bux-Ten®	343.4
Carbofuran	607.3
Chlordane	123.2
Dasanit	45.8
Diazinon	627.1
Dyfonate®	194.0
Heptachlor	377.4
Malathion	48.8
Methoxychlor	33.8
Phorate	856.8
Toxaphene	26.0
Total Insecticides:	5,543.6

B. HERBICIDES

Pesticide	Quantity (1000 lb AI)
Alachlor	1,941.8
Amiben	3,055.5
Atrazine	5,059.1
Butylate	1,825.9
CDAA	180.0
Dicamba	21.4
2,4-D	1,108.6
EPTC	90.0
Linuron	436.8
Propachlor	3,640.3
Simazine	93.8
Trifluralin	1,588.0
Vernolate	1,525.3
Total Herbicides:	20,566.5

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[a] MRI estimates based in part on data from Ref. 101.

TABLE B-VII

AGRICULTURAL USAGE OF PESTICIDES IN INDIANA, 1970[a]

A. INSECTICIDES

Pesticide	Quantity (1000 lb AI)
Aldrin	2,271.7
Azinphosmethyl	0.5
Bux-Ten®	22.8
Carbaryl	9.7
Diazinon	57.1
Heptachlor	268.5
Malathion	36.0
Methoxychlor	11.1
Phorate	10.5
Total Insecticides:	2,687.9

B. HERBICIDES

Pesticide	Quantity (1000 lb AI)
Alachlor	311.7
Atrazine	4,308.2
Chloramben	696.8
2,4-D	469.7
EPTC	47.7
Linuron	61.6
Propachlor	1,196.7
Trifluralin	171.0
Vernolate	35.0
Total Herbicides:	7,298.4

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[a] MRI estimates based in part on data from Ref. 102.

TABLE B-VIII

1973 RURAL INSECTICIDE AND HERBICIDE USAGE
160 FARMERS-JOHNSON COUNTY, IOWA[a]

A. INSECTICIDES

Pesticide	Quantity (1000 lb AI)
Aldrin	5.5
BHC	< 0.01
Bux-Ten®	1.2
Carbaryl	0.05
Carbofuran	2.8
Chlordane	< 0.01
Coumaphos	< 0.01
Dasanit	1.6
Diazinon	< 0.01
Dichlorvos	0.08
Dyfonate®	2.4
Endosulfan	0.1
Heptachlor	5.1
Lindane	0.2
Malathion	0.3
Methoxgchlor	0.1
Phorate	2.0
Ronnel	0.3
Toxaphene	0.2
Trichlorfon	< 0.01
Total Insecticides	21.8

B. HERBICIDES

Pesticide	Quantity (1000 lb AI)
Alachlor	17.5
Amiben	9.4
Atrazine	35.8
Bladex®	3.1
Butylate	15.0
Chlorbromuron	0.2
Chlorpropham	0.1
Colbex®[b]	(150)
2,4-D	1.0
Dicamba	0.2
EPTC	0.3
Linuron	1.5
Paraquat	0.2
Picloram	0.04
Propachlor	9.4
Sencor®	0.1
Simazine	0.04
2,4,5-T	0.8
Trifluralin	3.0
Total Herbicides	97.7

C. FUNGICIDES[c]

Pesticide	Quantity (lb. AI)
Captan	10.50
Zineb	3.75
Total Fungicides	14.25

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[a] MRI estimates based in part on data from Ref. 103.

[b] It is believed Colbex should be Cobex®, made by U.S. Borax. Formulation was not known--amount is in pounds as reported and is not included in total.

[c] Fungicide usage is for 1968 and is expressed in actual pounds.

TABLE B-IX

ESTIMATED POUNDS AND GALLONS OF COMMERCIAL FORMULATIONS OF SIX RESTRICTED PESTICIDES PERMITTED FOR SALE IN MARYLAND AS OF MARCH 15, 1971

	Reported[104]		MRI Estimate
	(lb)	(gal.)	(lb AI)
Aldrin	179,650	17,482	105,858
Chlordane	114,355	39,302	208,668
Dieldrin	26,806	6,408	13,084
Endrin	505	3,000	6,010
Lindane	15,365	3,123	10,087
BHC	3,000	4,810	20,440

TABLE B-X

PESTICIDE SALES REPORTED BY LICENSED DEALERS IN MICHIGAN FOR THE YEAR 1972[105/]

Pesticide	Sales Reported (lb AI) 1972
Aldrin	29,111
Calcium Arsenate	500
Calcium Cyanide	541
Cyano (Methylmercuri) Guanidine	726
DDT	66
Demeton	19,604
Dieldrin	11,745
Endrin	5
Heptachlor	130
Lead Arsenate	263,840
Mercuric Chloride	130
Mercurous Chloride	292
Mercury	216
Methyl Bromide	7,889
Methyl Parathion	3,061
Mevinphos	3,856
Parathion	118,737
Phenylmercuric Acetate	2,771
Phosphorus	0.1
Sodium Arsenite	24,165
Sodium Fluoroacetate	0.5
Strychnine	0.3
TDE (DDD)	3,187
Tetraethyl Pyrophosphate (TEPP)	1,732
Zinc Phosphide	556

[a/] Source: Michigan Department of Agriculture, Plant Industry Division.

TABLE B-XI

AGRICULTURAL USAGE OF PESTICIDES IN MICHIGAN, 1970[a]

A. INSECTICIDES

Pesticide	Quantity (1,000 lb AI)
Aldrin	117.8
Azinphosmethyl	18.6
Carbaryl	149.0
Diazinon	38.3
Malathion	109.9
Methoxychlor	76.0
Total Insecticides	509.7

B. HERBICIDES

Pesticide	Quantity (1,000 lb AI)
Alachlor	43.4
Atrazine	2,322.9
Chloramben	88.1
2,4-D	172.6
Linuron	129.2
MCPA	32.6
Propachlor	40.5
Trifluralin	3.6
Total Herbicides	2,832.9

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[a] MRI estimates based in part on data from Ref. 102.

TABLE B-XII

AGRICULTURAL PESTICIDE USAGE IN MINNESOTA, 1972[a]

A. INSECTICIDES

Organic Phosphates

Pesticide	Quantity (1,000 lb AI)
Azinphosmethyl	30.5
Diazinon	81.8
Dimethoate	2.5
Disulfoton	26.8
Dyfonate®	2.3
Fensulfothion	93.7
Malathion	0.4
Mevinphos	0.5
Phorate	356.3
Prophos	85.2
Trichlorfon	3.0
Subtotal	683.0

Chlorinated Hydrocarbons

Pesticide	Quantity (1,000 lb AI)
Aldrin	73.4
Chlordane	36.4
Endosulfan	14.9
Toxaphene	41.0
Subtotal	165.7

Carbamates

Pesticide	Quantity (1,000 lb AI)
Bux-Ten®	259.4
Carbaryl	272.2
Carbofuran	576.2
Subtotal	1,107.8

Total Insecticides: 1,956.5

B. HERBICIDES

Pesticide	Quantity (1,000 lb AI)
Alachlor	1,256.3
Amiben	1,430.7
Atrazine	3,082.5
Bladex®	81.6
Butylate	403.2
Barban	26.9
2,4-D	1,462.9
Dalapon	44.9
Diallate	62.0
Dicamba	38.0
Dinoseb	3.0
Endothall	2.5
EPTC	111.2
Linuron	58.9
MCPA	390.2
MCPB	7.5
Phenmedipham	1.3
Preforan®	87.8
Propachlor	3,614.9
TCA	292.5
Triallate	71.0
Trifluralin	586.4
Total Herbicides:	13,116.2

C. FUNGICIDES

Pesticides	Quantity (1,000 lb AI)
Difolaton®	15.3
Dithane M-45®	95.8
Maneb	100.6
Polyram®	23.0
Thiabendazole	0.5
Triphenyltin Hydroxide	13.7
Total Fungicides:	248.9

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[a] MRI estimates based in part on data from Ref. 106.

TABLE B-XIII

INSECTICIDE USAGE IN MISSISSIPPI, 1972[107/]

Insecticide		Quantity (1,000 lb AI)
DDT		7,000
Methyl Parathion		12,000
Toxaphene		17,000
	Total	36,000

TABLE B-XIV

ESTIMATED PESTICIDE USAGE ON ALL MAJOR CROPS IN WASHINGTON, BOLIVAR, AND SUNFLOWER COUNTIES, MISSISSIPPI, 1972[a]

	Quantity	
Pesticide	Estimated by County Agents	Estimates by Farmers
A. INSECTICIDES		
Aldicarb	84,000	11,803
Azinphosmethyl	9,000	-
Azodrin®	97,200	70,820
Bidrin®	44,000	156
Carbaryl	27,200	-
DDD	325,000	-
DDT	2,795,000	5,452,920
Dicofol	300	-
Dimethoate	5,000	3,246
Disulfoton	56,900	29,900
Endrin	13,600	7,776
Malathion	10,000	-
Methyl Parathion	1,705,500	2,093,122
Phorate	40,500	-
Strobane®	22,000	-
Toxaphene	6,390,000	10,157,400
Totals:	11,625,200	17,827,143

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[a] Data adapted from Ref. 108.

TABLE B-XIV (Continued)

Pesticide	Quantity Estimated by County Agents	Estimates by Farmers
B. HERBICIDES		
Alachlor	20,000	-
Amiben	9,600	-
Chloroxuron	6,000	-
2,4-D	11,500	-
Dalapon	70,000	-
2,4-DB	30,000	-
Dinitrophenol	210,000	664,961
Diuron	151,500	37,825
DSMA	5,000	-
Dyanap	20,000	-
EPTC	400	-
Fluometuron	220,000	472,072
Linuron	150,000	-
Molinate	10,000	-
Monuron	29,700	-
MSMA	1,490,000	1,751,880
Nitralin	157,000	-
Norea	50,000	-
Paraquat	10,000	-
Prometryne	40,000	-
Propanil	100,000	156,000
Silvex	500	-
2,4,5-T	21,500	39,000
Trifluralin	529,000	713,226
Vernolate	2,000	-
Totals:	3,343,700	3,834,964

TABLE B-XIV (Concluded)

Pesticide	Quantity Estimated by County Agents	Estimates by Farmers
C. DEFOLIANTS		
DEF Noles	325,000	60,669
Leaf-Drop	50,000	-
Sodium Chlorate	390,000	1,677,757
Shed-A-Leaf	45,000	-
Val-Drop	575,000	70,820
Totals:	1,385,000	1,809,246

TABLE B-XV

HERBICIDE USAGE BY MONTANA COUNTY WEED DISTRICTS FOR PERENNIAL WEED CONTROL, 1972[a]

Pesticide	Quantity (1,000 lb AI)
2,4-D	0.8
2,4-D amine	286.0
2,4-D ester	36.9
Dicamba	2.8
Picloram	4.9
2,4,5-T	6.6
Total Herbicides:	338.0

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[a] Data adapted from Ref. 109.

TABLE B-XVI

SOUTH CAROLINA PESTICIDE USAGE, 1970[110]

Pesticide	Estimated Range of Pesticide Use (lb AI)
Insecticide - Organophosphorus	
Azinphosmethyl and Ethyl	50,000 - 75,000
Azodrin®	50,000 - 100,000
Malathion	250,000 275,000
Methyl Parathion	1,000,000 - 1,250,000
Parathion	75,000 - 100,000
Phorate	12,000 - 15,000
Insecticides - Organo-Chlorine	
Aldrin	75,000 - 100,000
Chlordane	50,000 - 75,000
DDT	1,250,000 - 1,500,000
Endosulfan	20,000 - 40,000
Mirex	850 - 1,000
TDE (DDD)	None
Toxaphene	2,750,000 - 3,250,000
Insecticide - Carbamate	
Carbaryl	300,000 - 500,000
Furadan®/Temik® (Carbofuran/Aldicarb)	10,000 - 15,000
Lannate® (Methomyl)	15,000 - 25,000
Fungicides	
Copper Sulfate	40,000 - 80,000
Ferbam	90,000 - 110,000
Maneb	60,000 - 75,000
Sulfur	1,500,000 - 2,500,000
Nematocides	
DBCP	50,000 - 75,000
DB	1,250,000 - 1,500,000
Methyl Bromide	300,000 - 400,000
Mocap®/Dasinit® (Prophos/Fensulfothion)	30,000 - 50,000

TABLE B-XVI (Concluded)

Pesticide	Estimated Range of Pesticide Use (lb AI)
Herbicides	
Atrazine	150,000 - 200,000
Chloroxuron	40,000 - 80,000
Def®/Folex Type	125,000 - 175,000
Diuron	40,000 - 80,000
Fatty Alcohols	200,000 - 300,000
Lasso® (Alachlor)	50,000 - 75,000
Herban® (Norea)	120,000 - 160,000
MH-30®	150,000 - 200,000
MSMA	50,000 - 60,000
Phenoxy's	100,000 - 200,000
Trifluralin	200,000 - 300,000

TABLE B-XVII

PRINCIPAL COTTON INSECTICIDES AND ESTIMATED AMOUNTS USED IN THE RIO GRANDE VALLEY, TEXAS - 1972[a]

Insecticide	Quantity (1000 lb AI)
Azodrin®	750
Ethyl Parathion	1,000
Methyl Parathion	7,000
Toxaphene	4,000
(Galecron®, Sevin®, Fundal®, Bidrin®, Systox®, et al)	250
Total Insecticides	13,000

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[a] Data adapted from Ref. 111.

TABLE B-XVIII

ESTIMATES OF PESTICIDE USAGE IN UTAH, 1971[a]

A. INSECTICIDES

Organic Phosphates

Pesticide	Quantity (1,000 lb AI)
Azinphosmethyl	10.5
Ciodrin®	1.3
Coumaphos	1.9
Diazinon	12.2
Dimethoate	1.8
Disulfoton	6.6
Ethion	1.5
Famphur	7.1
Fenthion	1.5
Imidan®	2.2
Malathion	47.1
Methyl Parathion	8.9
Naled	6.2
Oxydemetonmethyl	1.6
Parathion	63.8
Phorate	1.5
Ronnel	1.9
Trichlorfon	10.4
Miscellaneous	3.2
Subtotal:	191.2

Chlorinated Hydrocarbons

Pesticide	Quantity (1,000 lb AI)
Aldrin	2.2
Chlordane	45.4
DDT	11.0
Dicofol	1.6
Dieldrin	3.5
Endosulfan	2.8
Heptachlor	3.4
Lindane	1.5
Methoxychlor	2.4
Toxaphene	4.3
Miscellaneous	0.7
Subtotal:	78.8

Carbamates

Pesticide	Quantity (1,000 lb AI)
Baygon®	0.4
Carbaryl	12.1
Methomyl	0.5
Zectran	0.1
Subtotal:	13.1

TABLE B-XVIII (Concluded)

A. INSECTICIDES (con't.)

Inorganic Chemicals

Pesticide	Quantity (1,000 lb AI)
Arsenic Trioxide	25.0
Calcium Arsenate	2.5
Lead Arsenate	22.0
Sodium Fluosilicate	0.3
Sulfur	20.0
Subtotal	69.8

Miscellaneous

Pesticide	Quantity (1,000 lb AI)
Fundal SP	1.5
Karathane®	2.1
Metaldehyde	1.6
Morestan®	0.2
Omite®	1.1
Rotenone	4.9
Subtotal:	11.4

Total Insecticides: 364.3

B. HERBICIDES

Pesticide	Quantity (1,000 lb AI)
Amitrole	26.0
Atrazine	65.5
Bromacil	3.4
Chloroxuron	8.0
Cycloate	26.0
Dalapon	4.4
DCPA	9.0
Dicamba	4.9
Dinoseb	2.5
EDB	288.0
EPTC	6.2
Igran®	6.4
Monuron	3.2
Picloram	2.6
Prometone	10.1
Silvex	14.0
Simazine	16.2
Sodium Chlorate	8.4
Sodium Metaborate	10.5
2,4-D	200.0
2,4-DB	1.4
2,4,5-T	28.0
Trifluralin	32.8
2,3,6 TBA	4.0
TCA	0.9
Miscellaneous	6.0

Total Herbicides: 788.4

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a/ Data adapted from Ref. 112.

TABLE B-XIX

AGRICULTURAL USAGE OF PESTICIDES IN WISCONSIN, 1970[a]

A. INSECTICIDES

Pesticide	Quantity (1000 lb AI)
Aldrin	16.8
Bux-Ten®	109.5
Carbaryl	3.0
Diazinon	65.8
Heptachlor	8.4
Malathion	0.6
Phorate	370.0
Total Insecticides:	574.1

B. HERBICIDES

Pesticide	Quantity (1000 lb AI)
Alachlor	350.3
Atrazine	3,372.3
Chloramben	22.3
2,4-D	217.0
Linuron	17.1
MCPA	43.2
Propachlor	93.5
Trifluralin	8.4
Total Herbicides:	4,124.1

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[a] MRI estimates based in part on data from Ref. 102.

APPENDIX C

LIST OF FEDERAL/STATE COOPERATIVE EXTENSION SERVICE OFFICIALS, STATE OFFICIALS, AND OTHER EXPERTS CONTACTED IN THE SURVEY PER CHAPTER III, SECTION C

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This letter addressed personally to the
Director of Cooperative Extension
in each of the 50 States, and in Puerto Rico.

Under contract #EQC 311 from the Council on Environmental Quality, RvR Consultants are currently studying the production volumes and use patterns of major agricultural and other pesticides in the United States. We would like to ask for your assistance in this project in three areas.

Firstly, would you please send us a complete set of your State's current recommendations for the control of insects, weeds, diseases, and other pests. We are interested in such recommendations for all agricultural crops, fruits, vegetables, ornamentals, forest, home & garden, livestock, and recommendations involving industrial, commercial, public health and other uses of chemical pesticides.

Secondly, does any agency or individual researcher in your area conduct studies or keep records on actual pesticide use (by quantities of pesticides, acreage treated, etc.)? If so, could you please send us copies of reprints or reports on such studies, or advise us where this information might be obtained. If such information has not been published, could you please refer us to the group doing the work so that we may contact them directly.

Thirdly, does your State have a statewide chemical pesticide coordinator? If so, could you please give us his name and address? We may need to contact him later on in this study.

We are working on this contract on a rather tight schedule and would therefore much appreciate it if we could hear from you soon. Many thanks in advance for your assistance.

Very truly yours,

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This letter addressed personally to the
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New Jersey, South Carolina, Texas, Washington.

Under Contract #EQC-311 (funded jointly by the Council on Environmental Quality and the Environmental Protection Agency), we are currently studying the production volumes, distribution, use patterns and environmental impact potential of major agricultural and other pesticides. RvR Consultants cooperate in this study with the Midwest Research Institute of Kansas City, Missouri. Pesticide uses within the scope of our project include uses on agricultural crops, livestock, forest lands, home and garden, and for industrial, commercial, public health and other pest control purposes.

We understand that pesticide use data by products, quantities of active ingredients, and crops or other end uses have been collected as one of the routine tasks in the Community Pesticide Studies. We would much appreciate it if you would send us such data as may be available for the state or region in which your project operates. 1972 is the base year for our study, but if you do not have data for that year, information for any other recent time period would also be helpful. Please be assured that we will, of course, give appropriate credit to the sources of data that we may use in the final report on our study.

We are working on a rather tight time schedule in this project and would therefore be very grateful if we could hear from you at your earliest convenience. Many thanks in advance for your help.

Very truly yours,

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Mountain View, CA 94040

Dr. Percy B. Polen
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Frank Porter
Agricultural Chemicals Division
Stauffer Chemical Company
Westport, Conn. 06880

C. H. Russell
Agricultural Division
Monsanto Commercial Products Company
St. Louis, MO 63166

E. H. Schwarze
Witco Chemical Corporation
Pioneer Division
Perth Amboy, New Jersey 08862

Arthur W. Sheldon
M & T Chemicals Inc.
Rahway, New Jersey 07065

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Stauffer Chemical Company
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American Cyanamid Company
Princeton, New Jersey 08540

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Philadelphia, PA 19105

H. J. Thome
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E. I. duPont deNemours & Company
Wilmington, Dela. 19898

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Monsanto Industrial Chemicals Company
Monsanto
St. Louis, Missouri 63166

David A. Webb
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Koppers Company, Inc.
Pittsburgh, PA 15219

John R. Weinert
Products & Industrial Chemicals
USS Chemicals
Pittsburgh, PA 15230

R. E. Werley, Jr.
The Ansul Company
Marinette, Wisc. 54143

Dr. R. D. Wessel
Research & Development
Chevron Chemical Company
Richmond, CA 94804

Dr. Dale E. Wolf
E. I. duPont deNemours & Company
Biochemicals Department
Wilmington, Del. 19898

E. N. Woodbury
Pesticide Control Services
Hercules Incorporated
Wilmington, Delaware 19899

Thomas C. Zinninger
Velsicol Chemical Corporation
Chicago, Ill. 60611

RvR CONSULTANTS
P. O. BOX 553 SHAWNEE MISSION, KANSAS 66201
TELEPHONE 913/722-5795

ROSMARIE VON RÜMKER, SC. D.

June 1973

This letter addressed personally to an executive in each of the 26 chemical companies that are basic producers of one or more of the study products.

Under contract #EQC-311 from the Council on Environmental Quality, Washington, D. C., we are currently conducting a study on the properties and use patterns of some 25 pesticides in the United States. This work is carried out jointly by the Midwest Research Institute (MRI) of Kansas City, Missouri and RvR Consultants.

Your company's product(s) identified below are among our study products. Thus, we are seeking your assistance in furnishing us the information set forth in the attached form. We wish to present the required data on each product as completely and accurately as possible and would therefore appreciate your cooperation in answering each question on the form. One copy is intended for your files, one is to be returned to us.

Please send us, along with the completed form, two copies each of your technical bulletin on the product, and two copies each of sample labels for the most important formulations in which the product is sold.

We are working on this contract on a rather tight schedule and would therefore much appreciate it if we would hear from you at your earliest convenience. Please write or call if there are any questions.

Many thanks in advance for your assistance.

Very truly yours,

RvR CONSULTANTS

Dr. Rosmarie von Rümker

RvR:fh
cc: Dr. J. C. Davies III, CEQ
Washington, D. C. (Project Officer)
Dr. E. W. Lawless, MRI
Kansas City, Mo.

RvR #29/Pesticide Summary
Contract #EQC-311

List of Study Products.

NOte: Pesticides for which we are seeking information from your company are marked. One or more of these products may have been included in the AID Pesticide Manual for which you furnished us information last year. Insofar as that information is still current, it need not be duplicated. For these products, please complete only pages 6 and 7 of the form, plus all other items on which you may have more recent data.

Herbicides:

- atrazine
- MSMA
- trifluralin
- alachlor
- bromacil
- diuron
- 2,4-D
- chlorates

Insecticides:

- chlordane
- aldrin
- toxaphene
- carbaryl
- carbofuran
- parathion
- methyl parathion
- malathion
- disulfoton
- diazinon

Fungicides:

- pentachlorophenol
- creosote
- captan
- maneb
- organotin pesticides

Fumigants:

- p-dichlorobenzene
- methyl bromide

Two sets of forms are attached for each product marked. Please complete one and return it to us, the second one is for your use.

Product Identity

Common name(s):

Tradename(s):

Chemical name:
(ACS-accepted terminology)

Structural formula:

Molecular weight:

Physical and Chemical Properties of Active Ingredient

Physical state:

Specific gravity:

Solubility in -

-water at 20°C:
at 30°C:

-organic solvents:
(State in general terms for common organic solvents. Give specific solubility in at least two organic solvents.)

-lipids, fats:

Melting point:

Boiling point:

Vapor pressure:
(Give vapor pressure at two different temperatures if available.)

Flammability:

Stability:

Analytical Methods:

1st preference: Approved AOAC method (give reference).
If not available, list other standard method(s) by literature or other reference(s).

Hazards to Humans

Toxic action:
(Describe briefly if known.)

Acute toxicity to laboratory animals-

- oral:

- dermal:

- inhalation:
(State LD-50 (LC-50 for inhalation toxicity) to rats and/or other laboratory animals.)

Irritating to-

- eyes:

- nose & throat:

- skin:
(Answer "yes" or "no", assuming operator exposure under high temperature, high humidity conditions. Indicate whether or not sensitization may occur.)

Other hazards:
(Specify, or answer "none".)

Specific antidote(s):
(Specify, or answer "none".)

Chronic toxicity:
(Describe briefly. Give highest no-effect level(s) observed in 2-year tests, specify animal species.)

Cumulative toxic effects:

Allowable daily intake (FAO/WHO):

Residue tolerance(s):
(Give range of established U.S. tolerances and indicate tolerances applicable to the most important commodities.)

Circle toxicity category applicable to the active ingredient.

MAMMALIAN TOXICITY AND PRECAUTION CATEGORIES

Category	I	II	III	IV
Description	Highly toxic	Moderately toxic	Slightly toxic	Relatively non-toxic
Acute oral LD-50, mg/kg	Less than 50	Over 50 - 500	Over 500 - 5,000	Over 5,000
Acute dermal LD-50, mg/kg	Less than 200	Over 200 - 2,000	Over 2,000-20,000	Over 20,000
Acute inhalation LC-50, µg/l	Less than 2,000	Over 2,000-20,000		
Dose probably lethal to a 150 lb. man	A few drops to one teaspoonful	One teaspoonful to 1 oz.	Over 1 oz to 1 pt. or 1 lb.	Over 1 pt. or 1 lb.
Signal word required on label	Danger -Poison Skull & Cross-bones	Warning	Caution	None required

Hazards to the Environment

Toxicity to -
- fishes:
- lower aquatic organisms:
- birds:
- wild mammals:
- soil organisms:

(Refer to attached definition of "Wildlife toxicity categories" and enter appropriate statement /highly, moderately, slightly toxic, or relatively non-toxic/ for each group of organisms. Attach summary of supporting data if available. If toxicity to these organisms not known, so state.)

Build-up in food chains (Answer "yes", "no" or "not known"):

Likelihood of movement away from treated areas by -
- volatilization:
- leaching:
- surface runoff-
  - -in water:
  - -on solids:
- wind erosion:

(Describe likelihood based on physical and chemical properties of product or on results of field tests, if available.)

Degradation in the environment

Chemical route:

Major degradation product(s) and their toxicity relative to the parent cpd.:

(Describe briefly if known. If not known, so state.)

Degradable by -

--biological organisms:

--non-biological factors:

--sunlight:

(Answer "yes", "no", or "not known".)

Overall rate of degradation:

Persistence in soil:

Carry-over to next season.

Precautions: State precautions necessary to prevent harm to the environment, including non-target organisms.

WILDLIFE TOXICITY CATEGORIES

"Highly toxic" means that severe losses may occur if the pesticide is used in or over a habitat containing the animals or organisms specified. "Use" of the pesticide in this context means use at recommended dosage levels including such overuse as may be expected in normal operations from overlapping swaths, inadvertant double treatment and/or miscalibration.

"Moderately toxic" means that moderate losses of the animals or organisms may occur under the operating conditions outlined in the preceding paragraph.

"Slightly toxic" means that slight losses or injury to non-target animals or organisms may occur.

"Relatively non-toxic" means that no losses or injury to non-target species are likely to occur, allowing for a considerable margin of overuse, misapplication and/or miscalibration.

Use Profile (U.S. uses only)

Target crops (List most important crops or other targets on which the product is used, in decreasing order of approximate quantity of product used for each purpose):

Target pests (List the pests /insects, mites, weeds, diseases, etc./ against which the product is used most often, in decreasing order of frequency of use):

Application rates (Give rate/s/ of application, in terms of active ingredient per acre, generally used on the above crops and pests. If product is used broadcast and banded, give rates for each type of treatment and indicate percentage of total acreage treated with the product receiving broadcast and band treatments, respectively):

Time and frequency of application (Indicate how many times per season the product is generally used on the same acreage or other target area, and at what time/s/ of the year):

Type of application (Indicate, in decreasing order of importance, the formulation/s/ and type of equipment most often employed in the use of the product):

Areas of use: Considering all major uses of the product, estimate approximate percentage of the total domestic consumption used in each of the following regions in 1972:

Northeast: %
Southeast: %
North central: %
South central: %
Northwest: %
Southwest: %

Total U.S. 100%

Note: If your company is not the only supplier of this product to the U.S. market, please answer this question in terms of the total U.S. consumption, regardless of the source of supply. Include agricultural as well as all other uses in your estimate.

APPENDIX F

COPIES OF CORRESPONDENCE ON SURVEYS OF PESTICIDE USE BY STATE AND MUNICIPAL AGENCIES

MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Missouri 64110
Telephone (816) 561-0202

July 13, 1973

Dear Sir:

Midwest Research Institute is conducting a study for the President's Council on Environmental Quality. Part of our task is to determine the kinds and amounts of pesticides purchased by state governments. Our interest includes all types of pesticides (herbicides, insecticides, fungicides, rodenticides, etc) purchased by such departments as Fish and Game, Forestry, Public Health, Highways, Parks, Public Works, Agriculture, and others that you may have in your state. Note that we are not asking for data on pesticides used by the general public or by federal agencies in your state.

If your department can provide this information, we would appreciate receiving it. A form and an example is provided for your convenience in reporting your state's pesticide usage.

If your department cannot supply this information, could you please do one of the following:

1. Forward copies of this letter to those departments which are major purchasers of pesticides and ask them to supply us with this information; or

2. Provide us with names and addresses of those departments which are major purchasers so that we may contact them directly.

It is important that reasonable estimates of the total amounts of "active ingredient" are obtained for each pesticide used by our state governments. Your cooperation will be of value to the Council on Environmental Quality and will be greatly appreciated.

Very truly yours,

Alfred F. Meiners

Alfred F. Meiners
Principal Chemist

AFM/dw

Return to:
MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Missouri 64110
Attn: Dr. Alfred F. Meiners

SAMPLE COPY

PESTICIDE USE DATA FOR STATE GOVERNMENTS

STATE ______________ DATA FOR YEAR _____ (If other than 1972)

			Calculation of Amount AI Used[a]						
			As Purchased[b]		As Applied[b]				
Department	Purpose of Pesticide Use	Pesticide Used	% AI or Lb/Gal	Lb or Gal. Used	% AI or Lb/Gal	Lb or Gal. Used	Acres Treated	Lb AI/Acre	Estimated Total AI Used, Lb (or gal.)
Health	Mosquito control	Abate	4 lb/gal E.C.	15 gal.					60 lb
Parks	Weed control	2,4-D, butyl ester					50 acres	1 lb/acre (as 2,4-D acid)	50 lb
Buildings and grounds maintenance	Roaches, silverfish, etc.	Chlordane			2% spray	100 gal.			(2 gal.)
Rodent control	Rats	Warfarin	0.05% bait	1,000 lb					0.5 lb

SAMPLE COPY

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a/ AI = Active Ingredient; use whichever calculation method is most convenient.
b/ Technical product, concentrate or formulation.

MRI

MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Missouri 64110
Telephone (816) 561-0202

October 5, 1973

Dear Sir:

Midwest Research Institute is conducting a study for the President's Council on Environmental Quality. Part of our task is to determine the kinds and amounts of pesticides used by municipal governments. Our interest includes pesticides used by such departments as Parks and Recreation (herbicides, fungicides, insecticides, etc.), Rodent Control (rodenticides), Public Health (insecticides, etc.), and others that you may have in your city.

If your department can provide this information, we would appreciate receiving it. A form and an example is provided for your convenience in reporting your city's pesticide usage.

If your department cannot supply this information, could you please do one of the following:

1. Forward copies of this letter to those departments which are major purchasers of pesticides and ask them to supply us with this information; or

2. Provide us with names and addresses of those departments which are major purchasers so that we may contact them directly.

It is important that reasonable estimates of the total amounts of "active ingredient" are obtained for each pesticide used in our cities. Your cooperation will be of value to the Council on Environmental Quality and will be greatly appreciated.

Very truly yours,

MIDWEST RESEARCH INSTITUTE

Alfred F. Meiners

Alfred F. Meiners
Principal Chemist

AFM:mmd

MAILING LIST
PESTICIDE USAGE BY STATE AGENCIES

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Department of Administration
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John E. Short, Director
Bureau of Purchasing and Services
Department of Administration
Madison, Wisconsin 53700

Elias S. Galeotos, Purchasing Agent
Board of State Supplies
Cheyenne, Wyoming 82001

CONTACTED REFERRALS FROM STATE PURCHASING OFFICE

Department of Food and Agriculture
State of California
Agriculture Chemicals and Feeds
1200 N. Street
Sacramento, California 95814

Robert W. Roe, Purchasing Agent
Department of Highways & Transportation
Highway Administration Building
Dover, Delaware 19901

Department of Environmental Control
Tutwell Building
Dover, Delaware 19901

Department of Agriculture
Dover, Delaware 19901

Office of State Custodian
(AC 302 678-4611)
State House
Dover, Delaware 19901

Bureau of Material Management
Department of General Services
District of Columbia Government
613 G Street, N.W.
Washington, D.C. 20001
(202-629-3001)

Department of Transportation
2300 South 31st Street
Springfield, Illinois

Department of Conservation
602 State Office Building
Springfield, Illinois

Department of Agriculture
Ellington Agriculture Center
Nashville, Tennessee

Department of Mental Health
300 Cordell Hull Building
Nashville, Tennessee 37219

Department of Conservation
2611 West End Avenue
Nashville, Tennessee

Department of Corrections
1007 Andrew Jackson State Office Building
Nashville, Tennessee 37219

Department of Education
100-B Cordell Hull Building
Nashville, Tennessee 37219

Game and Fish Commission
Game and Fish Building
Ellington Agriculture Center
Nashville, Tennessee

Department of Transportation
817 Highway Building
Nashville, Tennessee 37219

Military Department
National Guard Armory
Sidco Drive
Nashville, Tennessee

Mr. R. E. Flaherty, Director
Equipment & Procurement
Texas Highway Department
Texas Highway Building
Austin, Texas 78701

Mr. Clayton Garrison, Executive Director
Texas Parks & Wildlife Department
100 John H. Reagan Building
Austin, Texas 78701

Mrs. Evelyn Ricks, Purchaser
Texas Department of Corrections
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Huntsville, Texas 77340

MAILING LIST - SURVEY OF PESTICIDE USAGE BY MUNICIPALITIES

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Albuquerque, New Mexico 87103

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Purchasing Department
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68 Mitchell S.W.
Atlanta, Georgia 30303

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124 West 8th
Austin, Texas 78701

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City Hall
Bismarck, North Dakota 53501

Finance Commission
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Casper, Wyoming 82601

Purchasing Agent
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City Hall
Chicago, Illinois 62521

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Cheyenne, Wyoming 82001

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Cincinnati, Ohio 45202

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General Offices
City Hall
601 Lakeside, N.E.
Cleveland, Ohio 44114

Administrative Departments
City Hall
Colorado Springs, Colorado

Purchase Board
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Columbus, Ohio 4315

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Dallas, Texas 75202

Puschasing Agent
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226 West 4th Street
Davenport, Iowa

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Finance Department
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Department of Purchases and Supplies
2 Woodward
Detroit, Michigan 48226

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Denver, Colorado 30202

Purchasing Agent
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Duluth, Minnesota

Purchasing Divison
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1000 Throckmorton
Ft. Worth, Texas

Purchasing Agent
City Hall
Helena, Montana 59602

City Hall
900 Brazos
Houston, Texas 77002

Weed Control
Health Department
Houston, Texas 77002

Purchasing Central
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Indianapolis, Indiana 46204

Comptroller's Office
City Hall
Louisville, Kentucky

Central Supply Stores
935 Logan
Louisville, Kentucky

City Hall
555 South 10th
Lincoln, Nebraska

Purchasing Agent
321 East 2nd
Los Angeles, California 90012

Purchasing Agent
125 North Main Street
Memphis, Tennessee 38103

Purchasing Division
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Purchasing Department
City
200 East Wells
Milwaukee, Wisconsin 53202

Purchasing Department
City Hall
Minneapolis, Minnesota

Purchasing
111 South Royal
Mobile, Alabama 36602

Bureau of Purchasing
Finance Department
City Hall
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Department of Purchasing
Municipal Services Administration
Municipal Building
New York, New York 10007

Purchasing Department
Finance
200 North Walker
Oklahoma City, Oklahoma 73102

Finance Department
City Hall
108 South 18th
Omaha, Nebraska 68102

Service Center
Supplies Department
City-County Building
Pittsburgh, Pennsylvania 15219

City Treasurer
Supplies Department
City-County Building
Pittsburgh, Pennsylvania 15219

Finance Department
Municipal Services Building
Philadelphia, Pennsylvania 19107

Purchasing Division
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251 West Washington
Phoenix, Arizon 85003

Purchases andStationary
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Raleigh, North Carolina 27611

Supply Commissioner
City Hall
12th and Market
St. Louis, Missouri 63103

Purchasing Department
15 West Kellogg Boulevard
St. Paul, Minnesota 55102

City Hall
Military Plaza
San Antonio, Texas

Purchasing Department
Administrative Offices and Buyers
City Administration Building
San Diego, California

Purchasing Department
City Civic Center
San Francisco, California 94102

Purchasing Division
Purchasing Agent
Seattle Municipal Building
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Seattle, Washington 98104

City Hall
405 6th Street
Sioux City, Iowa 83626

Purchasing Department
200 Civic Center
Tulsa, Oklahoma

Procurement Office
499 Pennsylvania Avenue, N.W.
Washington, D.C.

REFERENCES

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6. Cornell Aeronautical Laboratory, Inc., "The Movement and Impact of Pesticides Used in Forest Management on the Aquatic Environment and Ecosystem," Contract No. 68-01-0125 for the Environmental Protection Agency, June 1972.

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